

**AN INVESTIGATION INTO THE KNOWLEDGE AND SKILL  
REQUIREMENTS FOR EFFECTIVE TEACHING OF TECHNOLOGY IN  
ENGLISH SECONDARY SCHOOLS**

**By**

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**A Doctoral Thesis**

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What is needed is

*“a sincere Hand, and a faithful Eye, to examine, and to record, the things themselves as they appear.”*

Robert Hooke, 1665. Micrographia

*“Nothing has more impact on a child’s achievement than the quality of teaching they receive and in the new standards for teachers we have prioritised the importance of classroom practice and subject knowledge.”*

Dame Sally Coates, 2014. Chair of the independent Review of Teachers’  
Standards

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## **Abstract**

This thesis is concerned with the knowledge and skill requirements to teach technology education. Technology education has an important part to play in the UK economy. There is great demand to produce a technologically skilled workforce and secondary school technology education is a key element in the supply of skilled engineering technicians and graduates. Whilst there have been improvements in the number of pupils choosing to study mathematics and science there has been a decline in those studying technology. The work in this thesis has focused on the subject of Design and Technology as it provides pupils with the majority of their compulsory technology education in England.

This thesis is comprised of four studies, adopting a mixed-methods approach. The first study characterised the background knowledge of Design and Technology teachers through a demographic analysis. In the second study observations were made on the adoption and teaching of a novel technology resource by trainee teachers. The third study analysed the opinions of teachers who attended a subject knowledge enhancement professional development course. In the fourth study the results of the previous studies were explored in further detail to triangulate findings and to test assumptions.

In the first study the admissions data of 341 trainee Design and Technology teachers over the academic years 2000-2001 and 2013-2014 inclusive was analysed. The key finding of this analysis was that 81% of Design and Technology teachers have their entry qualification in creative arts and design and not in a technology subject. This misalignment of subject knowledge was discussed to be a result of the existing training standards and hypothesised to be contributory to the lack of technology teaching, and over emphasis of design in Design and Technology.

The second study used observational methods to record how three trainee teachers adopted and taught lessons using a novel technology resource created for the study. The resource was designed to teach laser cutting and the design of mechanical systems. Subsequent analysis revealed the difficulties participants had in understanding and teaching the technology aspects of the projects. The existing practice, and collective knowledge of

teachers within the schools used in the study were found to create obstacles for the trainees in trying to implement technological content.

The third study developed a new professional development course for teachers to address the issues observed in the second study. The quantitative and qualitative data was obtained from 20 participant design and technology teachers before, during and after the course. Participants reported to be confidence in teaching technology, yet were unable to demonstrate a deep understanding of the subject content. Participants engaged with the procedural knowledge aspects of the course but not with the conceptual knowledge. They considered many aspects of technological and engineering content to be irrelevant to pupils.

The fourth, and final, study developed questionnaires to assess teacher and pupil reactions to the provision of 57 different technology projects resources and training sessions to 82 schools across London. Useable data were generated from 33 teachers and 458 pupils. Measurements of teachers' confidence in teaching the new Technology National Curriculum revealed that teachers' strengths were the making of products. The weaknesses were teaching modern mechanical and electrical systems. Pupils' motivation towards technology revealed positive attitudes, but they were unaffected by resources teachers considered to be novel. This study was used to triangulate the findings of the previous study and validate the claims made.

The major contribution to knowledge of this thesis is the quantified description and analysis of teachers' technology knowledge. The interrelationships of the distinct teacher knowledge domains were analysed to discover how they affect technology education. The main conclusion of this study is that teachers have difficulties in developing and teaching technology based schemes of work to meet the National Curriculum requirements. However, teachers appear unaware of this situation and consider themselves confident in teaching the technology curriculum topics. These difficulties have been caused by teachers' lack of compatible background subject knowledge, and were evident in the teaching of projects without secure technology content. This thesis recommends that a significant intervention is required to provide support to Design and Technology teachers to develop their knowledge and skills in teaching technology.

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## **Publications**

### Journal Papers

Jones, L. C. R., Tyrer, J. R., & Zanker, N. P. (2013). Applying laser cutting techniques through horology for teaching effective STEM in design and technology. *Design and Technology Education: An International Journal*, 18(3), 21–34.

Jones, L. C. R., Tyrer, J. R., & Zanker, N. P. (2012). Clocks as a Learning Tool. *Horological Journal*, 154(7), 322–325.

### Conference Presentations

Jones, L. C. R. (2015) Technology and Engineering Teacher Development Centre. *The British Watch and Clock Makers Guild Conference 2015*, 11<sup>th</sup> March 2015

Jones, L. C. R., Tyrer, J. R., & Zanker, N. P. (2014). Teaching Engineering to Non-Engineering Teachers. *Engineering Education Research Special Interest Group 2<sup>nd</sup> Annual Symposium: The Sustainable Impact of Engineering Education Research 2014*, Northumbria University, 20<sup>th</sup> May 2014.

Jones, L. C. R., Tyrer, J. R., & Zanker, N. P. (2012). Clocks as a Learning Tool. *The Design and Technology Association: Education & International Research Conference 2012*, Keele University, 6<sup>th</sup> – 7<sup>th</sup> July 2012.

### Reports

Mitchell, A., & Watson, E., & Zanker, N. P., & Jones, L. C. R. (2015). London Schools Excellence Fund, Self-Evaluation Toolkit, Final report, Enhancing the teaching of STEM through Design and Technology (Mindsets STEM Enhancement Project) LSEFR1210

Zanker, N. P., & Jones, L. C. R. (2014). Evaluation Report of The Design and Technology Association Summer School 11 and 12 July 2014.

## **Glossary**

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CDT	Craft, Design and Technology
D&T	Design and Technology
EFA	Exploratory Factor Analysis
HESA	Higher Education Statistics Agency
ICT	Information and Communications Technology
IMI	Intrinsic Motivation Inventory
ITT	Initial Teacher Training
IQR	Interquartile Range
ISTE	International Society for Technology in Education
JACS	Joint Academic Coding System
KS1 (2,3,4)	Key Stage 1, 2, 3 and 4
MAR	Missingness at random
MCAR	Missingness completely at random
MDF	Medium Density Fibreboard
Mdn	Median
MNAR	Missingness not at random
PGCE	Post Graduate Certificate of Education
STEM	Science, Technology, Engineering and Mathematics
TP(A)CK	Technological Pedagogical Content Knowledge
Pupil	Learners studying at school under the age of 18
Student	Learners studying at university

# 1. Introduction

## 1.1. Problem Statement

### 1.1.1. The importance of Technology Education

The importance of Science, Engineering and Technology education to the UK economy was highlighted in 2002 in the SET for Success report (Roberts, 2002). Since then Mathematics has been recognised and added to this list to create an important area of the school curriculum. The significance of Science, Technology, Engineering and Mathematics (STEM) education at all levels has now been widely accepted and many initiatives to promote STEM have been created, such as the National STEM Centre, STEMNET, the Arkwright Scholarship Trust and WISE.

The reason that STEM education is so important in the UK is the significant demand for engineering technicians and graduates (Atkins, 2015; IMechE, 2011). Based on an estimated need for an additional 100,000 STEM graduates each year, from 2012 to 2020, the Royal Academy of Engineering predicted a shortfall of 10,000 STEM graduates a year (Harrison, 2012). Therefore, it is clear that there is an increasing demand for individuals with the knowledge and skills taught within the STEM subjects.

The teaching of Mathematics and Science is clearly evident in the English School Curriculum. However, this cannot be said for Technology and Engineering. Whilst elements of these subjects can be found in Computing, Design and Technology (D&T), Information and Communications Technology (ICT) and Physics they are not clearly defined as their own disciplines within the national curriculum.

There are many alternative definitions for technology, which have been made more complex by the conversational use of the word.

*“Technology is an everyday term but its colloquial use misrepresents the complexity of technology as a creative purposeful activity aimed at enhancing people’s lives through the development of products, systems and environments.” (Moreland & Cowie, 2007, p. 213)*



The definition of technology education to which this thesis is most closely aligned has been defined by Sir Robert Malpas (2000) as:

“Technology is an enabling package of knowledge, devices, systems, processes and other technologies, created for a specific purpose. The word technology is used colloquially to describe either a complete system, a capability, or a specific device.”

*(Malpas, 2000)*

This thesis work is also synonymous with the description of Engineering and Technology Education by Barak and Hacker (2011) who use the term to describe a rigorous, fundamental, subject that supports the education of all learners:

*“[...] technology education is about fostering student’s knowledge, aptitudes, and skills related to addressing scientific, technical and social-cultural dimensions in the process of design, problem solving or inventing new artifacts and technological systems”*

*(Barak & Hacker, 2011, p. ix)*

Incorporating a holistic STEM education into the curriculum will increase pupils’ understanding of how things work and improve their use of technology (Bybee, 2010). Technology is a crucial part of STEM and pupils’ use of technology can help with innovation, inspiration and creativity (Beyers, 2010; Bull & Garofalo, 2009; Eisenberg et al., 2003). Technology education can also improve performance and perceptions of science and maths (Alexander, Tillman, Cohen, Ducamp, & Kjellstrom, 2013; Lamberty, 2008).

It is important not to confuse technology education with the popular area of educational technology. The term educational technology encompasses technology that teachers and pupils use to teach and learn. It includes using tools such as interactive white boards, online learning platforms, audience response systems, self-paced learning software, computer games, information and communication technology (ICT), multimedia software and planning and administrative software (BECTA, 2009).

Educational technology is different from the technology education within STEM. Technology education is intertwined with engineering and is a mixture

of academic, practical and vocational knowledge and skills which appear in several subjects (Harrison, 2011).

### **1.1.2. The trends in Technology Education**

With the importance placed on technology as a part of STEM, it is essential to monitor current trends in cohorts studying these technology rich subjects. Mathematics and Science education is compulsory for all pupils from Key Stage<sup>1</sup> 1 (KS1) through to post-14 Key Stage 4 (KS4) as part of the UK National Curriculum. Technology education however is only compulsory for pupils up to Key Stage 3 (KS3). Looking at post-16, A-Level education data reveals trends in the areas pupils choose to study; Figure 1.1 shows the number of examinations sat for each STEM A-Level subject: Biology, Chemistry, Computing, D&T, ICT, Mathematics, Further Mathematics and Physics. Art and Design has also been included as a comparison to the 'design' in Design and Technology. The data covers all UK candidates sitting summer examinations in the years 2004-2014 inclusive. Data are from publications by the Joint Council for Qualifications (JCQ), a membership organisation representing the seven largest national awarding bodies offering qualifications in the UK (JCQ CIC, 2014).

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<sup>1</sup> The National Curriculum in England is divided into 4 Key Stages. Key stages 1,2,3 and 4 are for children ages, 5-7, 7-11, 11-14 and 14-16 respectively. The national curriculum defines targets and assessments for the end of each Key Stage.

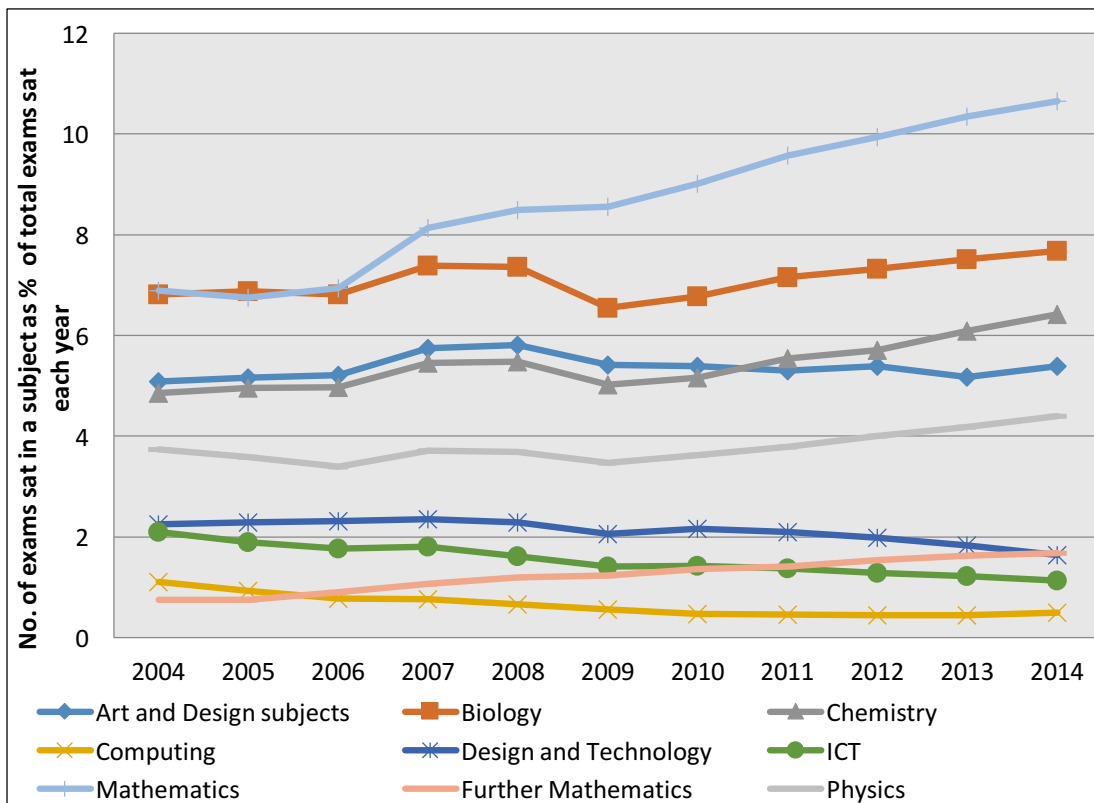


Figure 1.1 Joint Council for Qualifications GCE A-Level Results 2004-2014 (All UK Candidates)

The data in Figure 1.1 have been normalised to the number of total A-level examinations sat each year. The results of linear regression analysis of these data are shown in Table 1.1. This shows a strong positive trend in the number of pupils choosing to take examinations in mathematics and further mathematics. Conversely there is a negative trend in pupils sitting examinations in computing, D&T and ICT. This negative trend may have a detrimental effect on the number of pupils pursuing technology-based higher education and careers as the engineering profession is dependent on D&T education to expose young pupils to design, realisation, practical and technical skills and experience of making working things (Harrison, 2011).

Table 1.1 Linear Regression of A level subjects 2004-2014

Variable(Subject)	df regression	df residual	F	p	B	R <sup>2</sup>
Art and Design subjects	1	9	.099	.760	.007	.011
Biology	1	9	5.201	.049*	.066	.366
Chemistry	1	9	27.234	.001***	.131	.752
Computing	1	9	45.548	.000***	-.061	.835
Design and Technology	1	9	29.094	.000***	-.059	.764
ICT	1	9	187.342	.000***	-.091	.954
Mathematics	1	9	306.606	.000***	.415	.971
Further Mathematics	1	9	619.011	.000***	.099	.986
Physics	1	9	11.943	.007**	.069	.570

Significant at \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed. \*\*\* $p < .001$ , two-tailed.

Analysis undertaken by Matthews (2014) using Higher Education Statistics Agency (HESA, 2014) data reveals the comparably slow growth of engineering and technology subjects within higher education. The data compare the number of enrolled students in 1996-97 with those in 2011-12. 1996-97 was an important year as it was the beginning of another expansion in higher education as a consequence of the publication of the Dearing Report on Higher Education (NCIHE, 1997) and the government's plan to get 50% of young people into higher education (Bathmaker, 2003). Between 1996-97 and 2011-12 there was rapid growth in newer subjects, such as media studies which experienced an increase of 360% in student numbers. In 2011-12, media studies had more enrolled students than mechanical engineering. Engineering and technology subjects have grown 20.9% in the same timeframe, analysed against a total rise in student numbers of 42.2%. Of the 27,980 students studying engineering and technology subjects between 1996-97 and 2011-12, 20,935 were from overseas. This therefore resulted in an actual increase of 7,045 (6.8%) UK home students in 15 years.

There are other areas where technology education has been failing to engage pupils. Only 13% of the STEM workforce in the UK are women (Botcherby & Buckner, 2012). Three decades of initiatives to increase the number of women in physics and engineering has therefore made little impact (E. Smith, 2011).

### 1.1.3. Design and Technology

The data presented previously suggest a problem in school technology and engineering education. Whilst D&T education is compulsory across KS 1, 2

and 3, Key Stage 3 D&T was chosen as the most appropriate area of investigation for this research. This is because D&T contains the largest amount of technology content in the compulsory curriculum. The significant decline in the subject selection post KS3 suggests an impact can be made here.

The purpose of studying D&T, taken from the latest version of the National Curriculum, is aligned to the goals of STEM. D&T should be able to provide pupils not only with technology education but the awareness of the importance of technology to the UK economy and also identify the potential for further education and subsequent employment:

*“Design and technology is an inspiring, rigorous and practical subject. Using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts, considering their own and others’ needs, wants and values. They acquire a broad range of subject knowledge and draw on disciplines such as mathematics, science, engineering, computing and art. Pupils learn how to take risks, becoming resourceful, innovative, enterprising and capable citizens. Through the evaluation of past and present design and technology, they develop a critical understanding of its impact on daily life and the wider world. High-quality design and technology education makes an essential contribution to the creativity, culture, wealth and well-being of the nation.”* (Department for Education, 2013a)

These goals should be realised by studying technology topics such as those in Table 1.2. This thesis aims to identify and understand why pupils learning this range of technical knowledge and skills are not opting for the subject beyond Key Stage 3 and into further and higher education.

Table 1.2 Expected student progression in D&T

Across KS3 pupils should:	In early KS3 pupils should also know:	Across KS3 pupils should:
<p>use learning from science to help design and make products that work</p> <p>use learning from mathematics to help design and make products that work</p> <p>understand the properties of materials, including smart materials, and how they can be used to advantage</p> <p>understand the performance of structural elements to achieve functioning solutions</p> <p>understand how more advanced mechanical systems used in their products enable changes in movement and force</p> <p>follow procedures for safety and hygiene and understand the process of risk assessment</p> <p>use a wider, more complex range of materials, components and ingredients, taking into account their properties</p> <p>use a broad range of manufacturing techniques including handcraft skills and machinery to manufacture products precisely</p> <p>exploit the use of CAD/CAM equipment to manufacture products, increasing standards of quality, scale of production and precision</p> <p>apply a range of finishing techniques, including those from art and design, to a broad range of materials including textiles, metals, polymers and woods</p>	<p>how to classify materials by structure e.g. hard woods, softwoods, ferrous and non-ferrous, thermoplastic and thermosetting plastics</p> <p>about the physical properties of materials e.g. grain, brittleness, flexibility, elasticity, malleability and thermal</p> <p>how more advanced electrical and electronic systems can be powered and used in their products</p> <p>how to use simple electronic circuits incorporating inputs and outputs</p> <p>about textile fibre sources e.g. natural and synthetic and fabrics e.g. plain and woven</p> <p>how to select and modify patterns and use in textile construction</p> <p>make use of specialist equipment to mark out materials</p> <p>use a broad range of material joining techniques including stitching, mechanical fastenings, heat processes and adhesives</p> <p>use CAD/CAM to produce and apply surface finishing techniques, for example using dye sublimation</p> <p>investigate and develop skills in modifying the appearance of materials including textiles and other manufactured materials e.g. dyeing and applique</p>	<p>how materials can be cast in moulds</p> <p>how to make adjustments to the settings of equipment and machinery such as sewing machines and drilling machines</p> <p>how to apply computing and use electronics to embed intelligence in products that respond to inputs</p> <p>make use of sensors to detect heat, light, sound and movement such as thermistors and light dependant resistors</p> <p>how to apply the concepts of feedback in systems</p> <p>how to control outputs such as actuators and motors</p> <p>how to use software and hardware to develop programmes and transfer these to programmable components for example, microcontrollers</p> <p>how to make use of microcontrollers in products they design and manufacture themselves</p> <p>how to construct and use simple and compound gear trains to drive mechanical systems from a high revving motor</p> <p>adapt their methods of manufacture to changing circumstances</p> <p>recognise when it is necessary to develop a new skill or technique</p>

Source: Design and Technology Progression Framework (Design and Technology Association National Curriculum Expert Group for D&T, 2014)

## 1.2. Scope of Research

Technology education will only become more important to the growth and expansion of the UK economy with the increasing demand for STEM skills (Sainsbury, 2007). The trends in secondary, further and higher education reveal that without intervention, the necessary number of STEM qualified

pupils and students will not be reached. This will have a significant detrimental effect on the UK economy. The evidence in the education trends suggest that there is a potential problem and/or missed opportunity to enthuse and retain technology students during compulsory technology education. The subject of D&T at KS3 contains a significant amount of the technology content in the National Curriculum and is therefore an appropriate focus for this work.

The key findings in reports from the Office for Standards in Education, Children's Services and Skills (Ofsted) were the lack of relevant expertise in secondary school D&T teachers for the broad range of technology content within D&T (Ofsted, 2008, 2011b). The reports were drawn from evidence from Her Majesty's Inspectors' evaluations of the provision of D&T in schools. These findings suggest that the quality of teaching in D&T is limiting pupils' experience.

This thesis therefore investigates the teaching of technology at this point in order to identify and understand the observed attrition of pupils beyond KS3 education.

### **1.3. Research Questions**

This research aims to identify the knowledge and skill requirements for teaching technology education in Design and Technology, and to map current provisions in teaching of technology in D&T. Specifically research questions are:

- What is the knowledge background of D&T teachers?
- What influence does teacher knowledge have on technology education?
- What professional development activities can support technology education?
- Are teachers confident in teaching the new National Curriculum provision for D&T?

## 1.4. Research Methodology

Traditionally, research in the Social Sciences can be described as either following a positivist paradigm using quantitative methods or an interpretivist paradigm using qualitative methods. Positivism follows an objective approach to science utilising the scientific method of observation and experimentation. It is the principal paradigm used in the natural sciences and uses quantitative methods of data generation and analysis. Following the positivist paradigm the research would be objective, educational researchers should eliminate their biases and remain uninvolved with their objects of study. Although a positivist approach can provide answers through measurable variables and hypothesis testing, it is criticised by anti-positivists as being reductionist. Interpretivism is subjective rather than objective. Interpretivists argue that the behaviour of individuals studied in social science can only be understood by the researcher sharing their frame of reference. The qualitative methods used in this paradigm strive to describe, interpret and provide understanding, where meaning is important. The criticism of the subjective approach is the weakness in validating qualitative data (Cohen, Manion, & Morrison, 2007; Johnson & Onwuegbuzie, 2004).

A mixed methods methodology sits between the objective and subjective methodologies, Figure 1.2. Mixed methods is a third approach to research which does not seek to replace the traditional two but instead, incorporates elements of both to form a complete, in-depth understanding of the research area. It has been used to maximise strengths of both paradigms and minimise weaknesses of both a positivist and an interpretivist approach by combining quantitative and qualitative methods (Johnson & Onwuegbuzie, 2004; Johnson, Onwuegbuzie, & Turner, 2007).

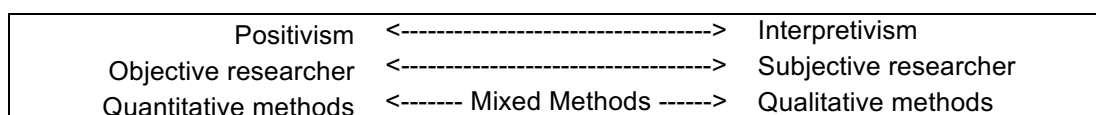


Figure 1.2 Spectrum of educational research methodologies  
Adapted from Cohen et al., (2007)

Triangulation can be used to combine qualitative and quantitative methods to be used for mixed methods research (Olsen, 2004). Triangulation is a multi-method approach utilised within social science research that attempts to explain in more detail the richness and complexity of human behaviour by



studying it from more than one perspective (Wilson, 2009). The strength of triangulation is that the use of more than one method can be beneficial as the limitations of one method are addressed by the strengths of another (Cohen et al., 2007).

### **1.5. Ethical Consideration**

This research was conducted in compliance with the Loughborough University Ethical Advisory Committee's guidance in relation to research with human participants. The ethical clearance checklist was completed for each study containing human participants. Informed consent was obtained prior to collection of data from participants and participants were made aware that the data collected would remain confidential, would be reported in an anonymous form and that participants could withdraw from the study at any time without reason.

### **1.6. Thesis Structure**

This thesis is presented in 8 chapters. Following this introduction, the chapters are:

Chapter 2 reviews the extant literature on the knowledge requirements for effective teaching, specifically technology education. This creates a framework which is used in analysis throughout the thesis. The literature review identifies the paradigms for teacher education, theoretical frameworks for teacher development and how teacher education can be analysed.

Chapter 3 reports a descriptive analysis of Post Graduate Certificate of Education (PGCE) student records from Loughborough University D&T initial teacher training (ITT). This initial study aimed to provide a demographic analysis of prospective D&T teachers. This provides information on the starting conditions of D&T teachers through investigation of the first degrees held by prospective teachers accepted onto the ITT programme.

Chapter 4 describes in-school testing of a technology rich project, conducted as the second study. The project contains both theoretical and practical technology that should be delivered as part of the National Curriculum.

Workshops and lesson observations allowed the exploration of factors affecting teacher ability to deliver technology education.

Chapter 5 is an evaluation of a Continuing Professional Development (CPD) programme introduced to address problems identified in the previous chapters. A range of questionnaires were used at different time intervals to capture quantitative data to triangulate qualitative results of the previous study.

Chapter 6 is the study of the implementation of a range of new technology resources during the Design and Technology Association “STEM into Action with D&T” programme. Questionnaires and evidence from classroom teaching provide an assessment of teacher technology education competency compared to the D&T national curriculum.

Chapter 7 presents the main discussion of the thesis in order to answer the research questions. A summary of the key findings are also presented.

Chapter 8 contains the main conclusions, implications and suggestions for further work. The contribution to knowledge made by this thesis is also presented.

The details, aims and key findings of the 4 studies conducted in this research are listed in Table 1.3. The key findings offer a clear explanation as to the development of the research.

Table 1.3 Studies conducted and their progression

Study Design	Specific study aims	Findings which led to the next study
1. Chapter 3. Statistical analysis of PGCE student records from D&T ITT programme	To identify the existing content knowledge of D&T teachers Provide demographic information about D&T teachers	Generated the percentages of D&T who have prior qualifications in engineering and technology subjects. The view from this first study identified the suspected root cause of technology education problems in D&T. It is proposed that this lack of sufficient technology subject knowledge would prohibit teachers from effectively delivering technology education. The subsequent study investigated the teaching of technology while analysing evidence of teacher's subject knowledge.
2. Chapter 4. Using mixed methods to analyse a technology project in KS3 classrooms.	To evaluate teachers' ability to implement a theory and practical technology rich project.	Appropriate pedagogic theories were used to develop a technology project as part of the KS3 NC. The PGCE students in the study were mostly unfamiliar with the technology content they were asked to deliver. Pupils were able to engage with technology despite teachers' reservations. Evidence that teachers' knowledge and beliefs were not suitable for this technology project. Teachers' deficiencies identified as the limiting factor in students access to technology. The next study investigated using CPD programmes to address problems identified in Study 2.
3. Chapter 5. Questionnaire evaluations of a single technology CPD course	Compare confidence in technology before and after the course. To understand teachers' perceptions of a technology focused CPD course. To provide quantitative evidence to validate results in prior study.	Confidence in teaching specific technology areas is measured. Teachers and students on the courses were unaware of many of the technical areas. Revealed a worrying lack of health and safety awareness associated with using technology. Study 2 and 3 were in depth and descriptive analyses of a specific technology area. Next study will expand to measure teacher ability over the entire curriculum. Study 4 also assesses the impact of CPD intervention methods.
4. Chapter 6. Use of self-assessment questionnaires to measure teacher technical competencies and pupil technology attitudes.	An assessment of teachers' technology teaching competency Impact of teachers' technological competency on student attitude to technology education. Evaluation of peer based CPD.	

1.7.

1.7.

## **1.7. Claims of originality**

The work detailed in this thesis comprises the following original work:

- Demographic analysis of D&T teachers' qualifications used to discover the distribution of teacher subject knowledge.
- Observation and analysis of the knowledge and skills required by D&T teachers to implement technology resources, using an adaptation of Shulman's (1986, 1987) teacher knowledge model.
- Quantitative and qualitative analysis of a subject knowledge enhancement course for the use of laser cutters in D&T.
- Quantitative and qualitative analysis of teachers' confidence in delivering the new D&T National Curriculum.
- Use of the Intrinsic Motivation Inventory instrument to assess pupils' intrinsic motivation towards the teaching of technology in D&T.

## **2. Literature Review**

### **2.1. Introduction**

This chapter provides a review of published literature concerning the requirements to become a technology teacher and how the technical skills of technology educators can be developed. Firstly, the literature was reviewed for theoretical models that could explain the distinctive knowledge and skill requirements of Design and Technology (D&T) teachers. The specific domains are discussed in relation to the current status of technology education in secondary schools in England<sup>2</sup>. The literature review has produced a suitable framework which has been used throughout the research as a tool for assessing teacher's actions. Secondly the development process for teacher education was reviewed from initial teacher training (ITT) through to continuing professional development (CPD). This identified the paradigms of how teachers learn and was used to select a method of assessment for teacher technology education capability. This is all discussed below.

### **2.2. Knowledge and Skill Requirements for Teachers**

“Arts or skills + knowledge = abilities”(Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956, p. 38)

In order to teach technology education, teachers must possess a mixture of knowledge and skills. Although these two words are commonly used interchangeabl in everyday conversation, there is a distinct difference between the two. Table 2.1 lists some definitions of knowledge and skills.

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<sup>2</sup> There are separate provisions for Scotland, Wales and Northern Ireland, which are beyond the scope of this enquiry.

Table 2.1 Definitions of knowledge and skill

Knowledge	Anything that is known. The three major classes of knowledge are declarative knowledge (knowing that), procedural knowledge (knowing how), and acquaintanceship knowledge (knowing people, places, and things). <sup>1</sup> The apprehension of fact or truth with the mind; clear and certain perception of fact or truth; the state or condition of knowing fact or truth.[Def. 4b] <sup>2</sup>
Skill	Expertise or accomplishment in any field; specifically, any complex, organized pattern of behaviour acquired through training and practice, including cognitive skills such as mathematics or chess, perceptual skills such as radar monitoring, motor skills such as juggling, and social skills such as non-verbal communication. <sup>1</sup> Capability of accomplishing something with precision and certainty; practical knowledge in combination with ability; cleverness, expertness. Also, an ability to perform a function, acquired or learnt with practice.[Def. 6a] <sup>2</sup>

Sources: <sup>1</sup>(Colman, 2014) <sup>2</sup>(OED, 2014)

Knowledge is the capability of the mind to hold information, while skills are practical capabilities that can be performed. This distinction is important in D&T as teachers and pupils must possess both knowledge of technology and the practical skills to use these technologies. The inclusion of knowledge, as well as practical skills, is what sets D&T apart from other subjects (Martin & Owen-Jackson, 2013).

There are many different factors and levels to effective education. The taxonomy of educational objectives has been classified as the goals of education (Bloom et al., 1956). Bloom *et al.* defined three domains of educational goals; cognitive, affective and psychomotor. The hierarchical categories of each domain are shown in Table 2.2. The cognitive domain was originally defined by Bloom *et al.* and contains the levels of intellectual outcomes for pupils. Anderson *et al.* (2001) produced a revised version of the taxonomy which made several modifications to the terminology, structure and emphasis. The six levels were changed from noun to verb form, with a reordering of the highest category. The categories were defined, in ascending order, as: 1. Remember, 2. Understand, 3. Apply 4. Analyse, 5. Evaluate, 6. Create. The taxonomy of the cognitive domain tracks the development of cognitive functions from remembering knowledge to analysing, evaluating and creating new solutions to solve problems. These are in line with the purpose of study for D&T, and can be used to evaluate current teaching practices to ascertain if they are meeting these higher order categories in technology.

The affective domain was developed by Krathwohl, Bloom, and Masia (1964) and encompasses the emotional aspects of education. This can significantly improve or obstruct a pupil's education as it includes interest, attitude, values and motivation.

The psychomotor domain contains physical skills but it was not completed by the original researchers who developed the first two domains. Simpson (1966, 1971) has categorised the psychomotor domain with explanations of the cognitive functions associated with motor behaviour (Singer & Cauraugh, 1985). Another notable classification of psychomotor levels, relative to this work, has been made by Ferris and Aziz (2005) which classifies specifically for practical engineering education.

Table 2.2 Taxonomy of educational objectives

a) <b>Cognitive</b>	b) <b>Affective</b>	c) <b>Psychomotor</b>
6.Evaluation	5.Characterisation by a value or value complex	5.Complex overt response
5.Synthesis	4.Organisation	4.Mechanism
4.Analysis	3.Valuing	3.Guided response
3.Application	2.Responding	2.Set
2.Comprehension	1.Receiving	1.Perception
1.Knowledge		

Note: The taxonomy for each domain is hierarchical; the most complex category is at the top, the simplest is at the bottom.

Sources: Bloom et al. (1956), Krathwohl et al.(1964) and Simpson (1966)

In the original publication by Bloom *et al.*, (1956) the taxonomy was intended for use in many educational purposes. This was recognised by Krathwohl (2002) who explains the variety of situations in which the taxonomy has been used since its publication.

*“The Taxonomy of Educational Objectives is a scheme for classifying educational goals, objectives, and, most recently, standards.”* (Krathwohl, 2002)

The taxonomy of educational objectives outlines the levels from basic to advanced in cognitive, affective and psychomotor performance. This has been used in the analysis of studies in this thesis to identify the level of teaching activities undertaken. However, the taxonomy of educational objectives does not categorise the actual knowledge or skills that should be possessed by teachers for effective teaching. A more detailed and subject specific model was therefore required.

### **2.3. Categorising Teacher Knowledge**

Effective teachers possess different types of knowledge. Theoretical models of teachers' knowledge have been developed since the mid-1980s. Many researchers have classified the domains of teacher knowledge in order to understand teachers' pedagogy (Banks, Leach, & Moon, 1999; Banks, 1996a; McNamara, 1991; Mishra & Koehler, 2006; Shulman, 1986, 1987; Turner-Bisset, 1999). These models are not specific to any field of study.

The classification of teacher knowledge began with Shulman (1986, 1987) who listed and described a set of seven categories to explain the knowledge range of teachers. The 1987 work of Shulman is seen as an influential paper on the future developments of the pedagogic development of teacher's subject knowledge (Ellis, 2007a). Shulman's knowledge domains are Content Knowledge, General Pedagogical Knowledge, Curriculum Knowledge, Pedagogical Content Knowledge, Knowledge of Learners and their Characteristics, Knowledge of Educational Contexts and Knowledge of Educational Ends, descriptions of each of these knowledge domains are listed in Table 2.3. The Cognitive Taxonomy of Educational Objectives can be used to explain Shulman's domain of content knowledge (Bloom et al., 1956; Shulman, 1986). The critical distinction made by Shulman was the identification of Pedagogical Content Knowledge. Shulman regarded this as the most significant domain as it identifies the specific knowledge required for teaching. It characterises the combination of subject information and teaching method. This overlap is how teachers organise, present and adapt their understanding to teach a variety of different learners and is a type of knowledge unique to teachers.



Table 2.3 Shulman's domains of teacher knowledge

<b>Knowledge Domains</b>	<b>Description</b>
Content Knowledge	A deep, well structured, understanding of the subject matter.
General Pedagogical Knowledge	The broad principles and strategies of classroom management and organisation that appear to transcend subject matter.
Curriculum Knowledge	Knowledge of the curriculum and the array of instructional materials available to teach a topic. Also includes the ability to relate current lessons to other subjects being learnt simultaneously and to the curriculum below and above the pupil's current level.
Pedagogical Content Knowledge	A combination of content and pedagogy that extends the knowledge of subject matter, to the knowledge of subject matter specifically for teaching.
Knowledge of Learners and their Characteristics	Knowledge of the people you are teaching.
Knowledge of Educational Contexts	Includes the workings of the group or classroom, the governance and financing of the school or the community and culture.
Knowledge of Educational Ends	Educational ends, purposes, and values and their philosophical and historical grounds.

Sources: (Shulman, 1986, 1987)

Shulman's (1987) classification can be split into two directions (Ellis, 2007a, 2007b):

- A revision of Shulman's work , in the case of Banks, Leach and Moon (1999),
- An extension of Shulmans' work to develop a more complex model as made by Turner-Bisset (1999).

Banks, Leach and Moon (1999; 2005) created their own model of teacher knowledge, Figure 2.1. There are similarities between the terminology used in the models of Banks *et al.* and Shulman (1987) but there are differences in the definition. Although subject knowledge is analogous to content knowledge, Banks *et al.* were critical of the definition of content knowledge in Shulman's model. Shulman viewed content knowledge as a static body that a teacher must possess. Banks *et al.* modify this in their definition of subject knowledge and categorised it as the constantly changing body of knowledge that teachers learn. The category of school knowledge encompasses Shulman's curriculum knowledge and also includes the transposition of subject knowledge. Pedagogic knowledge is also an extension beyond Shulman's. The main difference in the model is that Banks *et al.* show the importance of the interconnection and overlap between the different knowledge categories. Any individual knowledge type is insufficient unless integrated with the understanding of the others. For this reason the idea of

Shulman's pedagogic content knowledge has been divided into the knowledge classifications of Banks *et al.* At the centre of the model is the teacher's personal subject construct which comprises teachers experience and their belief of how to conduct good teaching. The model by Banks *et al.* can be used to plan the in service development of teachers. This model has been used by Banks (1996a; Banks et al., 2004) in analysing technology teachers, Table 2.4.

In the research by Banks *et al.*(2004) one of the responses by a teacher was criticism of the use of a knowledge model to describe teachers. In this the teacher accepts that subject, pedagogic and school knowledge are important but that the model does not describe the attitudes, enthusiasm and concern for pupils that a teacher has.

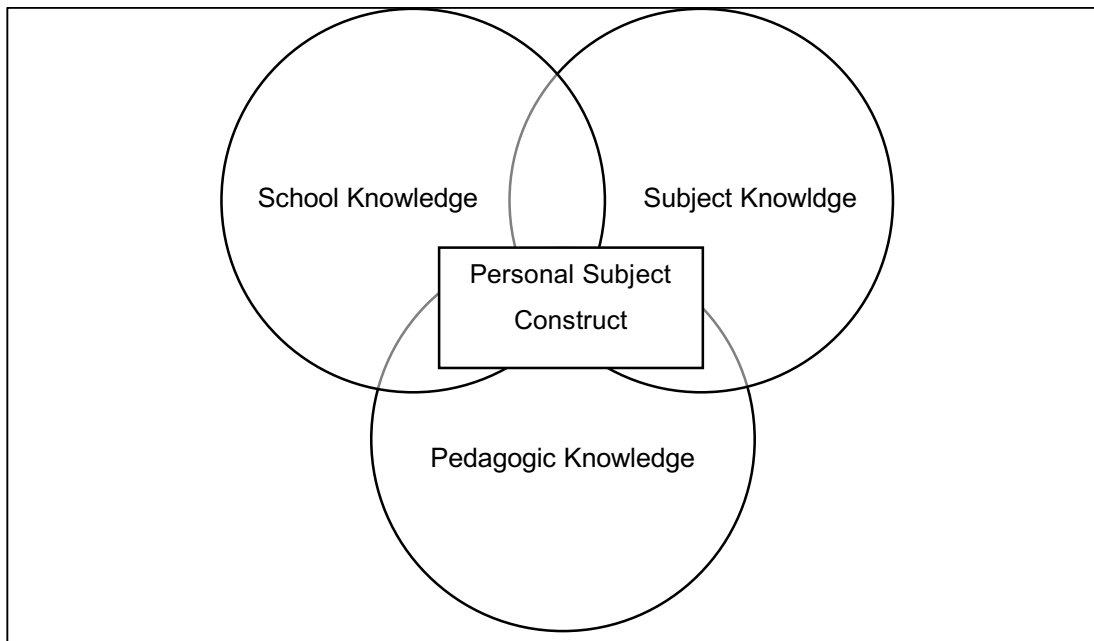


Figure 2.1 Teachers' professional knowledge (Banks et al., 1999, fig. 7.1)

Table 2.4 Example of the Teacher's professional knowledge model completed for design and technology in England.

Knowledge Category	Example completed for design and technology in England
School Knowledge	Facilities available in the school Appearance of school work rooms Expertise and history of other staff Status given to designing and making Interpretation of appropriate designing and making Status given to wider interpretations of technology education Contribution and status of personal expertise and history Prevailing ethos concerning issues such as pupil autonomy, staff - pupil relationships Sensitivity to political interpretations of technology – society
Subject Knowledge	Facts and concepts in any/some/all of the following domains: Food technology Resistant material technology Textile technology Electronic and communication technology Control system technology Methods of construction and manufacture in any/some/all of the above domains Practical expertise in these methods of construction and manufacture
Pedagogic Knowledge	National curriculum requirements Published teaching and learning resources Forms of assessment Use of questions Modeling appropriate practice Demonstration technique Use of analogies Task design
Personal Subject Construct	A combination of elements of school knowledge, subject knowledge and pedagogic knowledge which blend with other influences to provide a view of the purpose, value, content and methods of D&T as a school subject.

Adapted from (Banks et al., 2004)

Turner-Bisset (1996, 1999) developed a more complete model of teachers' knowledge bases, devised from Shulman's (1987) model. The knowledge bases of this revised model are listed in Table 2.5. In this model, Turner-Bisset has sub-divided Shulman's content knowledge into substantive subject knowledge, syntactic subject knowledge and beliefs about the subject. However, the major distinction in this model is the relocation of Pedagogical content knowledge. Turner-Bisset categorised pedagogical content knowledge as the amalgam of all the categories of a teacher's professional knowledge, rather than pedagogical content knowledge being just one of the knowledge bases (Ellis, 2007a). This defines a category of complete teacher knowledge but it may be difficult to distinguish and identify teachers' characteristics between the 11 sub categories.

Table 2.5 Knowledge bases for teaching

<b>Knowledge Base</b>	<b>Description</b>
Substantive subject knowledge	The facts and concepts of a discipline.
Syntactic subject knowledge	The way that propositional knowledge has been generated.
Beliefs about the subject	What a teacher believes is important to teach, and how to teach it.
Curriculum knowledge	The use and generation of creative methods and tools for teaching. Not just what is commercially available or governmentally prescribed.
General pedagogical knowledge	Knowledge about teaching, usually gained from practice.
Knowledge/models of teaching	Teachers' thought, knowledge and beliefs about teaching
Knowledge of learners: cognitive	Knowledge of child development and knowledge of a particular group or context of learners
Knowledge of learners: empirical	Knowledge of what a particular age range is like, behaviour, their interests, other factors influencing the learners and the child-teacher relationship
Knowledge of self	Teachers themselves understanding the nature of the job. Required for reflection and evaluation
Knowledge of educational contexts	Knowledge of schools, classrooms and all setting where learning takes place
Knowledge of educational ends	Educational ends, purposes, and values and their philosophical and historical grounds.
Pedagogical content knowledge	An amalgam containing all the other knowledge bases

Source: (Shulman, 1987; Turner-Bisset, 1999)

Mishra & Koehler (2006) developed the model of Technological Pedagogical Content Knowledge (TPCK), later referred to as TPACK (Koehler & Mishra, 2009). This is built on the foundation of Pedagogical Content Knowledge proposed by Shulman (1987). The use of technology was not considered important in Shulman's model as it assumed technology use in the classroom remained constant over a teacher's career. Compared to the modern classroom where there is an ever growing use of educational technology that a teacher must integrate into the practice. Technology in Mishra & Koehler's model can be both analogue and digital: books and chalkboards but more commonly now computers, electronic whiteboards and the internet. This model is intended to explain teachers use of educational technology but it can also be used to explain the integration of technology education (Gill, 2012; Harris & Felix, 2010).

Figure 2.2 shows how Mishra & Koehler (2006) have introduced Technological knowledge as a distinct knowledge base alongside Shulman's (1987) categories of Pedagogical and Content Knowledge. The model shows

that teachers have to integrate these three different knowledge bases to develop Technological Pedagogical Content Knowledge (TPCK/TPACK).

Technological knowledge is the understanding of specific technologies and it is the only model presented here that also incorporates the skill required to operate technology. It also includes the ability for teachers to continually adapt to changes in technology and to adopt new technology. Technological Content knowledge is not just the subject matter, but how the subject matter is changed or influenced by technology. Technological Pedagogical knowledge is how technology is used for teaching and learning.

Technological Pedagogical Content Knowledge emerges from the three separate categories to become the basis for effective teaching with technology (Koehler & Mishra, 2008, 2009; Mishra & Koehler, 2006). The model has been used for the design and analysis of teacher professional development (Koehler & Mishra, 2008; Mouza, 2011; Niess, 2005).

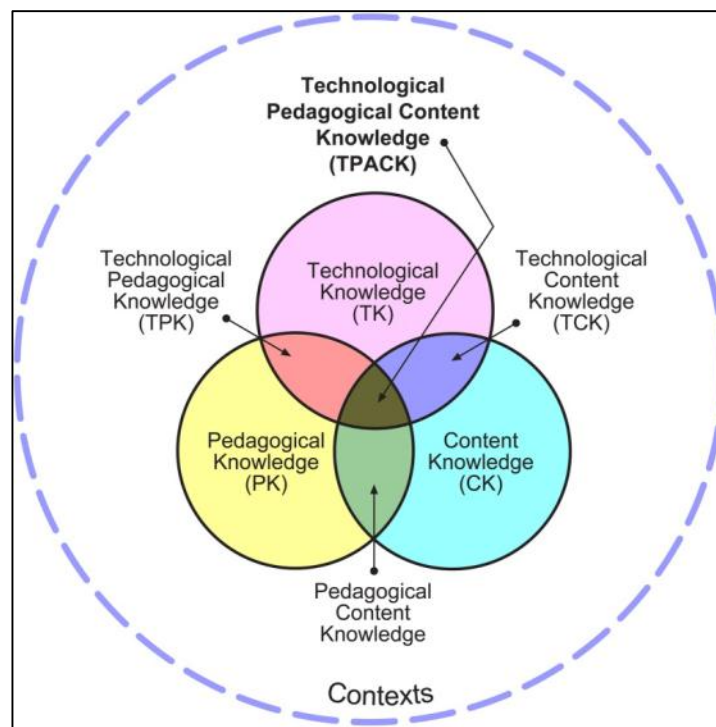


Figure 2.2 The TPACK framework and its knowledge components. Reproduced by permission of the publisher, © 2012 by <http://www.tpack.org>

The work of Angeli & Valanides (2009) confirms that TPCK is a unique form of knowledge but that greater understanding in the other knowledge forms does not automatically improve TPCK. Specific learning in TPCK is required.

The problem with the model is the context that surrounds TPCK. As the model is primarily focused on the integration of technology in teaching and

learning it is too simplistic a model to be used on its own to describe teacher knowledge. Even when considering technology education. The Contexts described in TPCK model must include all the other categories and issues described by Banks *et al.*, (1999) Shulman (1987) and Turner-Bisset (1999).

#### **2.4. Review of teacher knowledge categories**

A comparison of the different teacher knowledge domains identified in various models is presented in Table 2.6. This has revealed the common knowledge categories of the models reviewed. The common categories that featured in multiple models are the categories of content and subject knowledge, pedagogic knowledge, pedagogical content knowledge, curriculum knowledge, school knowledge and personal subject construct and beliefs. Literature on how these categories have been used in educational research across all subjects will be discussed before analysing the specific interpretation of the knowledge domains to D&T education. Although technology and technological pedagogical content knowledge are not found in other models these issues are important to this research and the impact across all subjects will also be reviewed.

It is important to note that although literature on pedagogical content knowledge has been extensive since Shulman's proposal, it is not evenly distributed across all subjects, with a higher proportion of articles reporting on science and mathematics (Ball, Thames, & Phelps, 2008).

Table 2.6 Comparison of teacher knowledge models

Shulman(1987)	Banks et al.(1999)	Turner-Bisset(1999)	Mishra & Koehler(2006)
Content knowledge	Subject knowledge	Substantive subject knowledge	Content knowledge
-	-	Syntactic subject knowledge	-
-	Personal subject construct	Beliefs about the subject	-
Curriculum knowledge	School knowledge	Curriculum knowledge	-
General pedagogical knowledge	Pedagogic knowledge	General pedagogical knowledge	Pedagogical Knowledge
-	-	Knowledge/models of teaching	-
-	-	Knowledge of learners: cognitive	-
Knowledge of learners and their characteristics	-	Knowledge of learners: empirical	-
-	-	Knowledge of self	-
Knowledge of educational contexts	-	Knowledge of educational contexts	Contexts
Knowledge of educational ends	-	Knowledge of educational ends	-
Pedagogical content knowledge	-	Pedagogical content knowledge	Pedagogical content knowledge
-	-	-	Technological Knowledge
-	-	-	Technological content knowledge
-	-	-	Technological pedagogical
-	-	-	Technological pedagogical content knowledge

#### 2.4.1. Content and Subject Knowledge

Although a different name is used across the alternative models they have all referred to a similar body of knowledge. This knowledge can be viewed as a static or dynamic in nature but in all the models it is the knowledge contained within and about a discipline.

Ellis (2007b) identified three problems with existing research on teacher's subject knowledge in relation to teacher's professional knowledge; dualism, objectivism and individualism. Firstly, dualism which considers that teachers' subject knowledge is described as both explicit and tacit. The theories on subject knowledge are context free and describe this knowledge as universally agreed. However, in practice subject knowledge is much more

dynamic and theory does not adequately describe the subject knowledge gained through practice.

Secondly Ellis identified the problem of objectivism. From this epistemological viewpoint subject knowledge is tangible and can be audited. This has made it appealing to educational policy makers. Hargreaves (2003) describes two mechanisms by which governments can make subject knowledge changes. Direct interventions demand compliance with legislation to ensure change, such as regulations for qualified teacher status or the national curriculum. Enabling interventions provide infrastructure and support to encourage innovation. An objective viewpoint can be detrimental to subject knowledge improvement if it is only utilised for excessive inspection and measurement to satisfy legislation but it can positively affect development when used to guide enabling interventions.

The third problem identified was individualism where subject knowledge is seen as a purely cognitive process in the mind of one teacher. This does not account for the relation of subject knowledge to other people or environments. Ellis considered the idea of subject knowledge belonging to the schools and is shared among teachers as well as individuals. The work of Shulman & Shulman (2004) supports this idea in that the theoretical and practical understanding of teacher learning should not just be concerned with individuals but must consider the context of a community of teachers.

The three problems identified by Ellis (2007b) must be carefully addressed and considered when using subject knowledge as an analysis tool in this work.

Content knowledge has been recognised as being very important to teaching. The minimum content knowledge requirement to becoming a secondary school teacher in England is a degree, or equivalent qualification (SI 2003/1662, 2003). Various degrees are said to be in alignment with D&T and the range of subjects suitable for D&T teachers are shown in Table 2.7 (Department for Education, 2014).



Table 2.7 JACS coded subjects that are mapped as suitable qualifications for D&T teachers

Subjects allied to Medicine	Nutrition
Veterinary Sciences, Agriculture and related subjects	Food and Beverage studies
Physical Sciences	Materials Science
Engineering	General Engineering, Civil Engineering, Mechanical Engineering, Aerospace Engineering, Naval Architecture, Electronic and Electrical Engineering, Production and Manufacturing Engineering, Chemical, Process and Energy Engineering & Others in Engineering.
Technologies	Minerals Technology, Metallurgy, Ceramics and Glasses, Polymers and Textiles, Materials Technology not otherwise specified, Maritime Technology, Industrial Biotechnology & Others in Technology.
Architecture, Building and Planning	Architecture, Building, Landscape Design, Planning (Urban, Rural and Regional) & Others in Architecture, Building and Planning.
Creative Arts and Design	Design studies, Crafts, Others in Creative Arts and Design.

Source: (Department for Education, 2014)

The suitability of these qualifications for enrolment on a D&T teacher education course, at Sheffield Hallam University, are explained by Lewis (1995):

*“A PGCE student with a degree in D&T is said to be in alignment [...], a product design student in reasonable alignment but a fine art degree would be out of alignment. Similarly, a HND/C qualification in engineering is in reasonable alignment but one in computer science is out of alignment.”* (Lewis, 1995, p. 47)

The alignment of people with the necessary design capability and technical knowledge as described by Lewis and the Department for Education is suitable. However, as discussed in detail below, in section 2.7.1 Standards, there is a high level of discretion given to the training provider.

Studies conducted around the time of the introduction of D&T to the national curriculum showed concern with technology knowledge. A review of the subject knowledge of PGCE and B.Ed. students training to be D&T teachers showed technological capability to be the lowest self-reported capability score compared to the design process, drawing capability, working with materials and information technology (Lewis, 1995). D&T teachers suffer from a technology subject knowledge problem that is caused by two factors: the breadth of technology content in the national curriculum and the

academic background of teachers (Evans, 1998). With an identified problem in technology subject knowledge it is critical to understand how subject knowledge deficiencies are addressed during ITT.

It has been recognised that one year PGCE ITT courses would not be able to deliver all subject knowledge required to teach the subject (Atkinson, 2011; Banks, 1997; Benson, 2009). Very few PGCE technology students have all the necessary subject knowledge from their first degree to teach the range of content within D&T. The Department for Education Circular 9/92 enforced that 66% of ITT had to take place in school. With other compulsory training required, the remaining time available for university led instruction on subject knowledge is low (Gregory & Nicholson, 1994; Lewis, 1995).

Subject knowledge is not subsequently addressed beyond ITT. The need for D&T teachers to improve their skills, knowledge and training in technology has been previously identified in reports from Ofsted. It was found to be common for schools to provide no external subject training (Ofsted, 2011b). Ofsted (2008) also identified lack expertise in modern technology such as Computer Aided Designing (CAD) and Computer Aided Manufacturing (CAM). Concern for both ITT and CPD in D&T have been presented by the Ofsted National Lead for Design and Technology (Choulerton, 2015).

The Teaching and Learning International Survey has identified key factors in England Secondary Schools CPD. Secondary school teachers in England have high participation in CPD with 92% participating in some form of CPD in a 12 month period. However the number of training days per teacher is low by international standards (Micklewright et al., 2014).

With low amounts of time spent on subject knowledge specific courses and the Ofsted report data, it would not be possible for a D&T teacher to acquire all the necessary technology knowledge if they did not already have a very strong background in technology. The effect of robust subject knowledge on teaching is described by Banks:

*“Teachers’ subject matter knowledge influences the way in which they teach, and teachers who know more about a subject will be more interesting and adventurous in their methods and, consequently, more effective. Teachers with only a limited knowledge of a subject may avoid teaching difficult or complex*

*aspects of it and teach in a manner which avoids pupil participation and questioning and which fails to draw upon children's experience.” (Banks, 1996b, p. 175)*

It has been demonstrated that improvements in content knowledge of in-service teachers can improve teacher self-efficacy and lead to improvements in teaching and learning (Hill, 2008; Swackhamer, Koellner, Basile, & Kimbrough, 2009). It could therefore be possible that problems with teachers subject knowledge cause them to avoid areas of technology education or fail to make technology education attractive to pupils; Causing or contributing to the problems identified in Chapter 1.

If subject knowledge is not taught in the ITT programme then the depth of a teacher's subject knowledge must be assumed to be contained in the degree qualification required to be a teacher. It is therefore essential to explore and understand the background subject knowledge of D&T technology teachers in more detail.

The importance of subject knowledge is summarised by McNamara:

*“In sum, the educational argument is that teachers' ability to plan lessons and teach effectively deploying a variety of appropriate teaching styles and methods, engage in the diagnostic assessment of pupils' learning, assess the quality of teaching materials and learning aids, have confidence to foster enquiry among children as active participants in their own learning, and their ability to analyse and reflect upon their teaching are all crucially dependent upon their subject matter knowledge and its application in the classroom.” (McNamara, 1991, para. 116)*

#### **2.4.2. Pedagogical Knowledge**

Anderson & Kim (2003) identified pedagogical content knowledge as the missing piece in mathematics education. In the USA, like England, teachers' pedagogical knowledge is typically developed through postgraduate education whereas content knowledge is developed during their undergraduate degree. Anderson & Kim argue that in order for teachers to become successful they must go beyond pedagogic knowledge and develop pedagogic content knowledge. Pedagogic content knowledge is unique to every individual and every class (Williams & Gumbo, 2011).

There is not enough time in an initial teacher training programme to develop or improve all the necessary content knowledge areas, as well as developing all the pedagogy associated knowledge required. Teachers learn the theory behind pedagogic methods during their postgraduate study and apply this during their teaching practices as a trainee teacher. In reference to mathematics teacher education:

*“In the limited amount of time teacher educators spend with prospective teachers it is impossible to address all of the mathematical topics they may come across in their future teaching.”* (Thanheiser, Browning, Moss, Watanabe, & Garza-Kling, 2010)

Torff and Sessions (2009) state that pedagogic knowledge is also a key component of a professional development course for teachers and that often professional development courses only focus on delivering content knowledge. In the study conducted by Torff and Sessions, school principals regarded pedagogical knowledge as the main cause of teaching inefficiency. Banks (1997) highlighted that teacher training courses should not pursue subject knowledge to the detriment of developing pedagogic and curriculum knowledge and skills.

### **2.4.3. Pedagogical Content Knowledge**

Pedagogical content knowledge is the unique category of knowledge belonging to teachers, combining their knowledge of the subject matter and knowledge of how to teach. Turner-Bisset (1999) went even further and proposed it as the consolidation of all the knowledge forms required by teachers.

In discussing the education of mathematics teachers, Thanheiser, Browning, Moss, Watanabe and Garza-Kling (2010) raise an interesting question exploring the reason for improving teacher content knowledge.

*“What is more important, the mathematical concept taught or the fact that a mathematical concept is developed using a “mathematical knowledge needed for teaching” lens?”* (Thanheiser et al., 2010)

This question highlights the importance for transforming content knowledge into pedagogical content knowledge. Although content knowledge is necessary and foundational to teach the subject it is not the only form of knowledge required. Teachers need both content knowledge and pedagogic content knowledge (Ball et al., 2008; Turnuklu & Yesildere, 2007). An expert in a particular field is not automatically an effective teacher of that discipline.

This proposes that effective teachers demonstrate evidence of pedagogical content knowledge, a mixture of content knowledge and pedagogical knowledge that is built up over time, as they are able to adapt their content knowledge to deliver it to the appropriate audience with appropriate pedagogical methods (Williams & Lockley, 2012). Teaching performance has been assessed using a model of pedagogical content knowledge (Inan, 2010; Turnuklu & Yesildere, 2007).

It can be difficult however to distinguish between evidence of content knowledge and pedagogical content knowledge. McNamara (1991) agrees with Shulman's importance on pedagogical content knowledge and the content knowledge it is built upon, but does not consider the two as practically separate categories. Bennett & Turner-Bisset (1993) (as cited in Turner-Bisset, 1999) found it impossible to differentiate between content knowledge and pedagogical content knowledge in teaching. This is because all knowledge delivered by a teacher is pedagogical in some way (Turner-Bisset, 1999).

Although it may be difficult to explicitly measure improvements in content knowledge and pedagogical content knowledge development is desired in teachers. Strawhecker (2005) found that a combination of in-school activities and field experience is required in combination with more formal content and pedagogy education to provide the greatest improvement in pedagogical content knowledge. In order to develop teachers with Pedagogical Content Knowledge Barrett & Green (2009) integrated the following elements in their teacher education programme: Reflective teaching practice, effective assessment and technology integration into a learning environment. Barrett & Green believe these methods allow teachers to continuously improve their content and pedagogic knowledge. Therefore, teachers would be

implementing new pedagogic content knowledge in their teaching, throughout their career.

#### **2.4.4. Curriculum Knowledge**

The national curriculum has always been a point of contention and confusion for technology education. Other school subjects are not repeatedly forced to account for their content and practice (de Vries, 2012). Some of the early disputes about technology education were the characterisation of technology as a distinctive subject. It was a clearly justified distinction that technology education should be its own subject and not just an application or field of science (Gardner, 1995; Kimbell, 1991, 1994). The Education Reform Act 1988 made the foundation subject of Technology a mandatory part of the National Curriculum. This introduced four attainment targets for Design and Technology and a fifth attainment target for Information Technology (Department of Education and Science & The Welsh Office, 1990). However the 1990 national curriculum introduction of technology suffered from a lack of identity and did not clearly state what technology is; making it problematic to define the scope of technology education (Barnett, 1994; Smithers & Robinson, 1992). The range of materials, contexts and technologies identified for study in the national curriculum has always been very broad. And since its inception there have been issues in balancing the range and depth of content taught (Farrell, 1992). The initial attempt to implement the subject of technology proved to be unmanageable in practice and had a negative effect on teachers' and pupils' work (Owen-Jackson, 2008).

The 'design process' was innovative at the time of introduction. It set out a guide for pupils to follow on each task that allowed teachers to critically assess student work. It has been described as a necessary step for the subject to become accepted in British Education as it allowed assessment (Kimbell, 1991). When introduced the 'design process' provided a real setting for pupils to demonstrate their knowledge and skill. However as extended design and make tasks have become the primary method of teaching D&T it has led, in some instances, to pupils pointlessly following a process, creating 'blue sky' designs that cannot be realised. It assumed capability would be acquired by pupils following this process, not through teaching, and has left pupils without the practical knowledge of tools, processes and materials they

require to be a good designer (Farrell, 1992). Teachers teach pupils a design process prescribed by the units of assessment, although this achieves high levels of measured performance it does not allow pupils room for risk-taking, creativity or innovative thinking (Atkinson, 2000b).

In 1995 the curriculum was revised and the foundation subject renamed to Design and Technology (Department for Education, 1995). This change included a focus on subject knowledge and the introduction of the product areas of resistant materials, systems and control, food and textiles (Owen-Jackson, 2008). The 1995 curriculum was easier to understand and introduced three types of assignments for pupils: designing and making products (DMA), focused practical tasks (FPT) and investigate, disassemble and evaluate products (IDEA) (Benson, 2009). Although the creation of these types of tasks was seen as positive at the time (Benson, 2009), Banks (2008) argues that they were inappropriate for what the subject has become:

*“It is clear that this traditional model of teaching is now inadequate as it teaches making skills without any underlying understanding, or development of other skills. Today we need teaching methods which match the broader aims that the subject has developed and which will lead to the wider view of design and technology capability.”* (Banks, 2008, p. 174)

Banks (2008) discussed the problem in curriculum balance of Design and Make Assignments and Focused Tasks. Although open ended design assignments offer pupils choice and therefore motivation, the pupils may not have the knowledge to complete it successfully. However, a focused task or teacher decided project can allow pupils to successively build up their design knowledge and skills and/or technology knowledge and skills.

With the current balance shifted towards design and make assignments which devote a lot of time to sketching design ideas and paper and pen based portfolio development, teachers appear hesitant to use the modern technology available to them, and included in the curriculum, that has been shown to improve the design process (Fraser & Hodgson, 2006; Musta'amal, Norman, & Hodgson, 2009).

The National Curriculum was updated in 2000, with revisions in 2004, (Department for Education and Skills & Qualifications and Curriculum

Authority, 2004) and with it came the prominence of new technologies such as ICT, CAD/CAM and smart materials. This version of the curriculum added an importance statement in order to clarify the purpose of the subject (Benson, 2009).

The D&T National Curriculum was updated again in 2007 (Qualifications and Curriculum Authority, 2007) and 2013 (Department for Education, 2013a). The latest version contains a clear purpose of study which includes creativity and imagination in product design using knowledge from mathematics, science, engineering computing and art. The subject content targets were split into design, make, evaluate and technical content. Martin (2013) states that teachers must adopt the changes to the curriculum:

*“As can be seen from the analysis of making and designing into eras, the demands on teachers have changed over time. It is important to remember, however, that these are periods of time and not models of curriculum delivery. If D&T is to be modernised then the response to that criticism lies in the practice of teachers in an educational context of performance tables and performance management. Such a change will be difficult and can perhaps only be achieved by teachers understanding the history of the subject and recognising the need to align their practice with current expectations.”* (Martin, 2013, p. 323)

Evidence suggests that the rapid and unclear developments in the national curriculum have resulted in confusion among teachers. There is still unrest for D&T teachers with delays to the publication of GCSE D&T curriculum (Department for Education & Gibb, 2015).

*“Comparative research has shown that the development of technology curricular across the world has been slow and implementation restricted, even when the new subject is ‘compulsory’”* (Banks, 2009b, p. 374)

With all the changes to the curriculum over its history and especially with the recent revisions to KS3 and KS4 it is unclear whether teachers have been able to keep up with the changes in demand.



### 2.4.5. School Knowledge

deVries (2006) was able to express a suitable simplification of the problem D&T has faced in developing an established form of school knowledge:

*“Of course one can not reasonably expect a new or drastically reformed school subject to result in concrete evidence of success in just 20 years. Yet, for several countries the fate of technology education depends on that.”* (de Vries, 2006, pp. 4–5)

As technology is a relatively new subject there has not been a long enough curriculum history. This has resulted in no common or shared solution as to how the subject should be taught. Technology education is different globally and there is no clear consensus as to what technology education is (Banks, 1996a, 1997, 2009b). Therefore each school will teach their own preferred design and make activities in D&T, even rejecting outside thinking:

*“Only a small number of trainees were given the opportunity for curriculum development.”* (Barlex & Rutland, 2008, p. 245)

In a study by Barlex and Rutland (2008) 13 out of 29 D&T trainee teachers cited the use of school rituals, expected or required behaviour patterns, as influencing their planning and teaching.

In a study by Banks *et al.* (2004) excerpts, reproduced below, of teachers' reports categorised as school knowledge show how school knowledge influences teaching:

*“It is important that I discover the expectations within the department [...] My own teaching can then work around this.”*  
(Banks et al., 2004, p. 150)

*“[...] the department ethos, or approach to teaching was the same across the board. [...] The Projects from year 7 upward were very closed in nature and pupils led by the hand through each assignment. This resulted in the pupils producing an end product identical to everyone else.”* (Banks et al., 2004, p. 150)

*“In this school the department is driven by the exam. That is all that is important. So I think technology here is too individualistic where industry is social.”* (Banks et al., 2004, p. 150)

Schools can be resistant to change their curriculum (Dow, 2006; Lewis, Baldwin, Dein, & Grover, 2005). Zanker (2005) described the occurrence of this problem with D&T PGCE trainees failing to move existing projects forwards. Trainees continue to do the same projects during their teaching practice without developing the higher levels of cognition in students. The 'steady hand game' project was the most common from the participants in Zanker's study and is an example of a project that does not develop teachers or students capability and often only requires KS2 knowledge in a KS3 classroom. Barlex and Rutland (2008) and Lewis (2005) give other examples of unchanging teaching practice following the schools preferred methods:

*"The product categories for the designing and making assignments reveal mainly well worn, tried, tested and rather uninspiring ventures. The relevance of some may be questioned. Many if not most teenagers have MP3 players that can hold a thousand tunes. Why would they want to design and make a CD rack?"* (Barlex & Rutland, 2008, p. 242)

*"wood is a main material and cabinets the project choice at GCSE"* (Lewis et al., 2005, p. 120)

Teaching in D&T is based on the model provided by the examination boards where subject knowledge is taught to pass exams not to support designing and making (Banks, 2009b; Lewis, 2003). This separation of knowledge and design activities can explain the uninspiring projects that schools choose to deliver. It has been argued that The National Curriculum, political situation and cost of resources constrained teachers to standardised projects that guaranteed pupil success which resulted in reduced pupil motivation (Lewis et al., 2005).

These uninspired teaching practices are evidence towards unchanging and unaware school knowledge. There is therefore a need to identify the typical teaching practice that occurs in D&T, compare that to best practices and evaluate how schools can adopt new practices in order to improve technology education.

#### **2.4.6. Personal Subject Construct and Beliefs**

Teachers' beliefs are not present in Shulman's (1987) original model, but have subsequently been added to the core of the model by Banks et

al.,(1999) and are considered to be a key separate knowledge category by Turner-Bisset (1999). The category of teachers' beliefs is not a teacher's whole belief system, but their educational beliefs. Although described as a cognitive category, beliefs can also be defined as affective. Teachers' educational beliefs cover a wide range of possible specific beliefs such as: self-efficacy, self-esteem, attribution beliefs, locus of control, epistemological beliefs and subject specific beliefs (Pajares, 1992).

The model by Banks, Leach and Moon (1999) introduced personal subject construct. This is different to just beliefs on its own as it combines school knowledge, subject knowledge and pedagogic knowledge to form a personal view on the value and content of the subject. Subject knowledge was identified as a major component in a teachers personal subject construct (Banks et al., 2004). The importance of teachers content knowledge, pedagogic knowledge and personal views on how they implemented technology was observed by Stein, McRobbie and Ginns (2000).

*“Technology teachers’ perceptions and understanding of the nature of technology heavily influences their perceptions of technology education and consequently shapes their teaching practice.”* (Forret, Edwards, & Lockley, 2013, p. 166)

It is recommended by van Es and Conroy (2009) that teacher education programmes should make future teachers question their beliefs about teaching in order to develop other ways for pupils to learn. Pre-service teachers are described by Pajares (1992) as insiders that do not need to redefine their situation. Pajares argues that new teachers have commitments to prior beliefs and that the situation of being a new teacher is not different enough from their prior classroom experiences for them to construct new beliefs. This is compared to law or medical students who must enter entirely new situations such as courtrooms and operating theatres respectively. To address the concerns of Pajares, teachers require some additional intervention to change beliefs.

Atkinson describes how the insular career path of teachers has resulted in the current beliefs of D&T teachers:

*“[...] designing was not part of a craft teacher’s training at the time designing was introduced in to the curriculum. This has had a*

‘knock-on’ effect over the past 20 years because of the cyclical movement of knowledge from teacher to pupils who then become teacher and lecturers training the next generation of teachers to design. This has inevitably resulted in many teachers in schools today still not displaying a deep understanding of the activity within their teaching” (Atkinson, 2011, p. 21)

Teachers’ beliefs can act as a barrier to change from external factors, such as curriculum change (Drageset, 2010). In a study by Mizell and Cates (2004) the beliefs of mathematics teachers were not significantly changed by additional content knowledge courses. There are examples in the literature of the effect of beliefs on teacher knowledge and teaching:

*“For our teachers, their ‘knowledge’ of the subject matter was as much a product of their beliefs as it was an accumulation of facts and interpretation.”* (Wilson & Wineburg, 1988, p. 557)

*“Teacher’s own beliefs and attitudes about the relevance of technology to students’ learning were perceived as having the biggest impact on their success”* (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012, p. 423).

Funkhouser and Mouza (2013) identified the importance of considering teachers beliefs in standalone technology courses. They found that pre-service teachers come with traditional teacher-centred beliefs about technology integration and that opportunity to reflect allowed teachers to develop their beliefs.

The work of MacGregor (2013) found that people who switch careers to become D&T teachers appeared to have a higher level of confidence in their teaching ability. Their prior experience may have contributed to improved technical skills, subject knowledge, beliefs and values. These new teachers did not encounter a negative school culture. This result shows that the improved subject knowledge from an existing technical career may have a significantly positive impact on becoming a teacher.

Although the beliefs in Table 2.8 were made under the 1999 National Curriculum there is not a significant difference between the importance statement then and the new purpose of study. Teachers perceived

importance of developing designer maker abilities in pupils may explain the re-use of tried, tested and uninspiring design and make assignments that do not reflect the breadth of the subject (Barlex & Rutland, 2008).

Table 2.8 Trainee response to suggesting learning outcomes justifying the place of design & technology in the compulsory school curriculum (Barlex & Rutland, 2008, p. 236 Table 1)

Learning outcome	Number trainees giving this response
Developing designer maker abilities	16
Developing problem solving abilities	11
Understanding the technology-society relationship	10
Drawing on knowledge and skill from elsewhere in the curriculum	8
Learning for everyday life	8
Developing creativity	8
Developing personal autonomy and collaboration skills	6
Operating in a unique learning environment	5
Developing environmental awareness	5
Vocational relevance	4
Becoming discriminating customers	3
Developing aspirational attitudes	1

Note: Sample of 29 trainees

In a study by Atkinson (2000b) the problem of teachers belief in the teaching models they use was described:

*[...] many teachers developed their process models using the GCSE guide-lines not only to enable pupils to meet all the units of assessment required in the examination, but also because they did not have a sound personal understanding of the intricate underlying principles involved in the activity. [...] Their belief in the models they devised was seen to be supported by the yearly success of their pupils in the examination. Unfortunately a combination of that success and the lack of understanding regarding the process has meant that teachers have cascaded these models down to pupils at lower secondary levels with unfortunate consequences. Highly structured, inflexible procedures which prevented rather than developed creative, innovative thinking have become the norm, even at the foundation stages of a pupil's secondary design and technology education."*

(Atkinson, 2000b, p. 276)

This belief identified by Atkinson (2000b) supports the reported teaching practice observed by Banks *et al.*(2004) and Barlex and Rutland (2008).

Teacher beliefs can be influenced during ITT. Rohaan, Taconis, & Jochems (2012) suggest that there should be more focus on content knowledge improvements for teachers as well as pedagogical content. The greater understanding of content leads to improvements in self-efficacy and beliefs. Similarly, Atkinson (2011) found that undergraduate and 2 year postgraduate D&T ITT programmes allow more time for development of subject knowledge for schools and this helps to develop positive attitudes towards D&T. A study by Gibson (2012) showed that industrial STEM placements for trainee teachers increase awareness of engineering and industry and increase understanding of the work that engineers and technologists perform. A change in teachers engineering and technology beliefs could cause an impact on pupils as teachers would be more able to explain the purpose for technology education in school.

#### **2.4.7. Technological Knowledge**

Technological knowledge was not included in the models by Shulman (1987), Banks *et al.*(1999) and Turner-Bisset (1999) so it must first be defined as a separate body of knowledge:

*“Technological knowledge is in some ways different from knowledge in other areas.”* (Norström, 2014, p. 20)

All iterations of the D&T curriculum have had a significant element of making (Lewis, 2003; Martin & Owen-Jackson, 2013; Martin, 2013). The knowledge required to design a product and then manipulate tools to make this design is different from other forms of knowledge:

*“[...] for example, knowing that metals can be joined by using heat is very different from knowing how to braze and weld.”* (Martin & Owen-Jackson, 2013, p. 69)

Technology knowledge is both conceptual (knowing that) and procedural (knowing how) (McCormick, 1997; Norström, 2014; Parkinson & Gill, 2009; Stein, McRobbie, & Ginns, 2002). These two sides to technological knowledge are not separated (McCormick, 1997).

Technological knowledge allows technological work, and includes skills and knowledge (Norström, 2014). Table 2.9 lists some of the knowledge and skills that are specific to the subject of D&T, and how with new developments in technology the list of requirements has grown.

Table 2.9 Skills and knowledge in the teaching of design and technology (Martin & Owen-Jackson, 2013, Table 5.1)

<i>Skills</i>	Up to 1960s	1970s	1980s	1990s	Present	Future?
Hand tools	✓	✓	✓	✓	✓	✓
Machine tools		✓	✓	✓	✓	✓
Drawing skills		✓	✓	✓	✓	✓
Designing skills			✓	✓	✓	✓
2D CAD			✓	✓	✓	✓
3D CAD				✓	✓	✓
Rapid Prototyping					✓	✓
<i>Knowledge</i>	Up to 1960s	1970s	1980s	1990s	Present	Future?
Properties of materials	✓	✓	✓	✓	✓	✓
Materials processing		✓	✓	✓	✓	✓
Manufacturing systems			✓	✓	✓	✓
Strategic knowledge			✓	✓	✓	✓
Technology and society					✓	✓

The importance of defining the skills and knowledge associated with technology is the distinction in how they are learned by teachers and taught. Skills cannot be taught in the same way as academic subject knowledge.

Not all technology knowledge can be acquired through design and making experience, technology subject knowledge must also be delivered through knowledge modules (Lewis, 2003). This suggests that although teachers may have some skill in operating a machine they may not be able to effectively teach with it without extra knowledge development.

Sutton (2011) analysed teachers use of technology in teaching using the International Society for Technology in Education (ISTE) standards for teachers. The ISTE standards are broad and cover the use of educational technology and also technology education (ISTE, 2008). Sutton's first finding from a teacher education programme was a disconnect between how teachers were asked to use technology in the classroom and how this integrated into the other teaching theories and methods they were taught. This supported an idea that without explicit instruction and authentic experience of technology use in teaching, teachers will not be able to

integrate new technological knowledge and skills into their classroom. Secondly teachers could not see the relevance of using technology, as they did not understand which content areas the particular technology was useful for. Teachers in Sutton's study also reported only having limited time with each technology which was not sufficient to develop a deep understanding. This time constraint prevented teachers from retaining knowledge and transferring it to their teaching. Banks (1997) found that teachers with existing practical experience were comfortable with teaching skills to students.

## **2.5. Levels of knowledge**

Having identified and discussed seven different knowledge categories possessed by technology teachers, the concept of surface and deep knowledge is discussed to explain the differentiation between levels of understanding in each of these categories.

### **2.5.1. Surface vs Deep Knowledge**

A dichotomy between surface and deep learning was established by Marton and Säljö (1976a, 1976b). The theory has been developed, tested and defined by Biggs (1987), Marton (1983) and Ramsden (1988). A surface approach to learning is the intention to complete the task requirements. A deep learning approach is the understanding beyond the task completed (Ramsden, 1988). Surface learning in school can give pupils the belief that school is an artificial situation that exists only to satisfy teacher's requirements (Entwistle & Marton, 1984). Deep teaching and learning provides a better understanding and is related to intrinsic motivation (Chin & Brown, 2000). Beattie, Collins and McInnes (1997) do however criticise the assumption that deep learning is always necessary. In some circumstances surface learning may be preferred. The differences between surface learning and deep learning are expressed in Table 2.10.



Table 2.10 Different approaches to learning (Ramsden, 1988, p. 19)

Deep Approach	<p>Intention to Understand</p> <p>Focus on 'what is signified' (eg authors argument)</p> <p>Relate and distinguish new ideas and previous knowledge</p> <p>Relate concepts to everyday experience</p> <p>Relate and distinguish evidence and argument</p> <p>Organise and structure content</p> <p>Internal Emphasis</p>
Surface Approach	<p>Intention to complete task requirements</p> <p>Focus on the 'signs' (eg the text itself)</p> <p>Focus on discrete elements</p> <p>Memorise information and procedures for assessments</p> <p>Unreflectively associate concepts and facts</p> <p>Fail to distinguish principles from evidence, new information from old</p> <p>Treat task as external imposition</p> <p>External emphasis</p>

Kimbell (1994) identified the problems in old methods of teaching pupils to be proficient in craft skills. These were suitable in Craft Design and Technology, but the acquisition of basic skills is not sufficient for modern D&T. Teachers at the time were even aware of the effect of surface learning of craft skills:

*“they can't design ... we have to tell them what to do”* (Kimbell, 1994, p. 68)

Cox (2007) exemplified the type of project taught in D&T that results in surface learning of skills. In these projects pupils are practicing skills and replicating actions shown by teacher, small amount of customisation are the 'design' elements of the project but pupils are not taught about the technology.

*“They cut a slot in the acrylic then placed it in the oven then twisted it or weaved the acrylic back through the slot they had cut. In short a simple project, with no in-depth analyses of the properties of acrylic or the reasons it behaves as it does when heated.”* (Cox, 2007, p. 61)

The concerns in relation to teacher knowledge that have been identified can be explained as being evidence of surface teaching and learning. D&T teachers would have some understanding of technology knowledge but if it is at a superficial or surface level of they will be unable to teach technology effectively.

## 2.6. Paradigms of Teacher Education

There are many theories to classify teacher education (Feiman-Nemser, 1990; Menter, 2010; Zeichner & Liston, 1990; Zeichner, 1983). Each of these paradigms or conceptual orientations describe the purpose of teacher education differently. These paradigms can be used to assist the development and evaluation of teacher education programmes (Volante & Earl, 2004). The four theories listed in Table 2.11 complement each other and contain models with corresponding paradigms.

Table 2.11 Comparison of teacher education paradigms

Zeichner (1983)	Feiman-Nemser (1990)	Zeichner & Liston (1990)	Menter (2010)
Academic*	Academic	Academic	-
Traditional-Craft*	Practical	-	-
Behaviouristic	Technological	Social efficiency	Effective*
Personalistic	Personal	Developmentalist	Reflective*
Inquiry-Oriented	Critical/Social	Reflective teaching	Enquiring*
-	-	Social reconstructionist	Transformative*

\*Naming convention used in this work.

The six paradigms identified in the literature were Academic, Traditional-Craft, Effective, Reflective, Enquiring and Transformative. Each of these paradigms for teacher education has their use during different stages of teacher education and development and are utilised to achieve different goals. The stage of education for each paradigm is described below.

Each paradigm also considers teacher education from different epistemological viewpoints, Table 2.12. These epistemologies affect what the teacher should be taught, how the teacher should be taught and the methods of assessment that can be used.

Table 2.12 Epistemologies of teaching paradigms

Teaching Paradigm	Epistemology
Effective (Behaviouristic)	Positivism
Reflective (Personalistic)	Interpretivism
Enquiring	Critical

Source: Calderhead(1993)

The epistemological viewpoints of the effective and reflective paradigms are in alignment with the research methodology of this thesis. Therefore these two paradigms are discussed in more detail and models of teacher development suited to each paradigm have been identified. This will allow for the identification of the stage of development of teachers during the analysis and discussion of results presented in this thesis by the particular epistemological viewpoint used.

### **2.6.1. Academic**

The academic model assumes that having a solid understanding of the subject knowledge and how to teach it is the most important aspect of teacher education (Volante & Earl, 2004; Zeichner & Liston, 1990). Supporters of the academic model emphasise the importance of teacher's academic preparation but teachers will not gain all the knowledge they require through subject-matter academic study (Feiman-Nemser, 1990). This is particularly true for the unique skills required to be a D&T teacher.

### **2.6.2. Traditional-Craft**

The traditional-craft model is the apprenticeship model for teacher education (Zeichner, 1983). It assumes teachers learn best by teaching (Feiman-Nemser, 1990). This is the origin of design and technology education, starting as apprenticeships in craft industries (de Vries, 2012; Martin, 2013). Elements of this model are still used in ITT today. Typically a trainee teacher will be assigned a mentor in school under whom they learn to be a teacher.

### **2.6.3. Effective**

The effective teacher model follows a scientific method for producing a teacher. It specifies a list of knowledge and skills that need to be acquired by a teacher and assesses achievement in these areas through explicit measurement. It could also be referred to as competency-based teacher education (Menter, 2010; Zeichner & Liston, 1990).

*“This general approach to teacher education emphasises the acquisition of specific and observable skills of teaching with are assumed to be related to pupil learning.” (Zeichner & Liston, 1990, p. 9)*

This model prioritises value for money and accountability making it favourable to governments. It was in line with previous versions of the

National Curriculum and national assessment system. It is politically driven compared to the reflective and enquiring paradigms of teacher education which have emerged from the teaching profession (Menter, Hulme, Elliott, & Lewin, 2010; Menter, 2010).

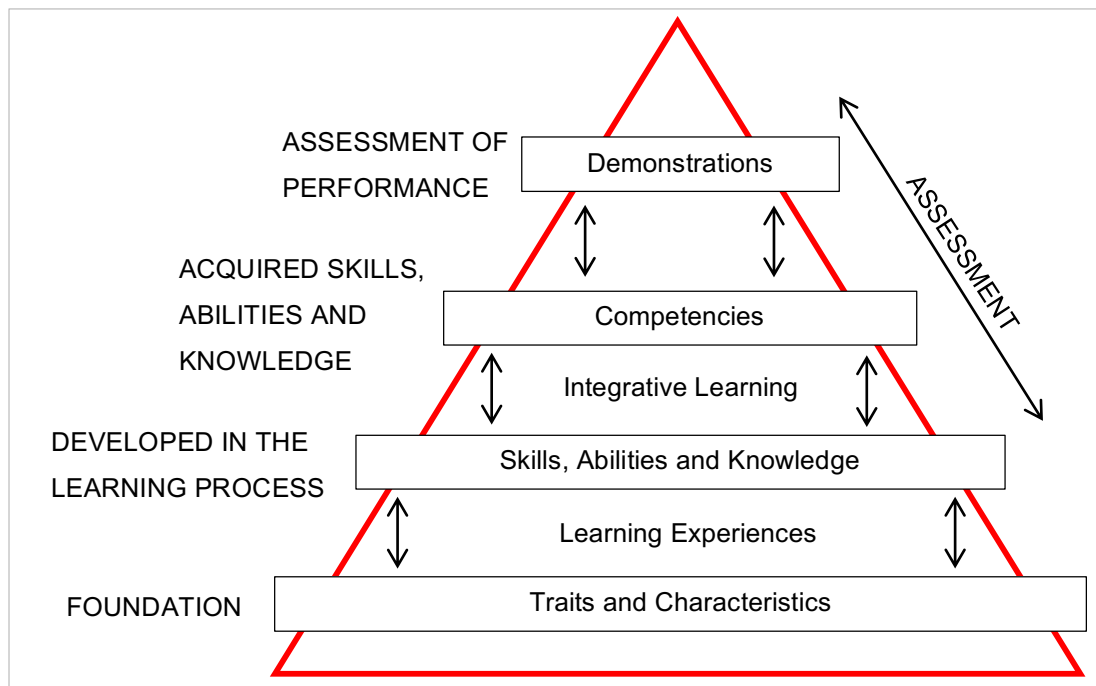
Table 2.13 shows the alignment of the teacher professional levels to the Dreyfus and Dreyfus (1980) and Berliner (1988) models. These show how as teachers provide evidence of competencies in order to progress through professional levels they are transitioning from Novice to Mastery or Expert. The Dreyfus and Dreyfus model has also been used in the education of other skill-based careers such as nursing (Benner, 1982).

Table 2.13 Alignment of teacher professional levels to competency models

Teacher professional levels (Training and Development Agency for Schools, 2007)	Dreyfus and Dreyfus (1980)	Berliner (1988)
Qualified teacher status	Novice	Novice
Teachers on the main pay scale	Competence	Advanced Beginner
Teachers on the upper pay scale	Proficiency	Competent
Excellent Teachers	Expertise	Proficient
Advanced Skills teachers	Mastery	Expert

The conceptual learning model (Jones & Voorhees, 2002; Voorhees, 2001), Figure 2.3, can be used to define competences, and explain their position relative to the knowledge and skills that teachers need to acquire.

Competence assessment is a useful way of assessing the performance of teachers as the competency model provides a measureable output (Voorhees, 2001). This numeric output is a suitable method for use in quantitative educational research and has been used extensively (Gumbo, Makgato, & Muller, 2012). However the difficulties in creating a competency model, especially for a national audience, is the agreement on the definitions of competence (Huntly, 2008).



Key Concepts	Definitions
Traits and Characteristics	are the foundation for learning, the innate make-up of individuals on which further experiences can be built. Differences in traits and characteristics help explain why people pursue different learning experiences and acquire different levels and kinds of knowledge and skills.
Skills, Abilities, and Knowledge	are developed through learning experiences, broadly defined to include school, work, participation in community affairs, etc
Competencies	are the result of integrative learning experiences in which skills, abilities, and knowledge interact to form bundles that have currency in relation to the task for which they are assembled.
Demonstrations	are the results of applying competencies. It is at this level that performance can be assessed

Figure 2.3 A hierarchy of postsecondary outcomes (Jones & Voorhees, 2002, para. 8, fig 1)

The criticism of using competence for evaluating teachers is that the method has been viewed as a reductive approach to teacher education (Turner-Bisset, 1999). Lists of acquired knowledge and skills monitored by competence thresholds do not reveal the actual complexity of teacher subject knowledge and it cannot be assumed that teachers can re-integrate all the separate competences acquired. The frequent changes and updates to D&T also mean that competency lists provided by the D&T Association become out of date (Gregory & Nicholson, 1994; Martin, 2008, 2011; Williams, 2009b).

#### 2.6.4. Reflective

The model of the reflective teacher is personal professional development through experience (Menter, 2010). The teacher creates a personalised

programme of their education and decides the goals and how to achieve them (Fuller, 1974).

*“According to this view, teacher education is a form of adult development, a process of ‘becoming’ rather than merely a process of education someone how to teach.” (Zeichner, 1983, p. 5)*

This paradigm is critical of structured methods of teacher education and supports a “student-centred” approach where teachers must be educated in the same supportive and stimulating environment as their pupils would be (Zeichner & Liston, 1990).

The extract below shows how the current teaching standards, in effect since September 2012, have a reflective approach to teacher progression and professional development. Teachers can self-evaluate and reflect on their current status in order to select their own programme of improvement. These new teaching standards no longer list 33 competences for QTS and 41 for core teachers (Training and Development Agency for Schools, 2007) but instead are reduced to 8 standards for teaching (Department for Education, 2013b). This is a change from an effective to a reflective approach to teacher education.

*“The standards have been designed to set out a basic framework within which all teachers should operate from the point of initial qualification. Appropriate self-evaluation, reflection and professional development activity is critical to improving teachers’ practice at all career stages. The standards set out clearly the key areas in which a teacher should be able to assess his or her own practice, and receive feedback from colleagues. As their careers progress, teachers will be expected to extend the depth and breadth of knowledge, skill and understanding that they demonstrate in meeting the standards, as is judged to be appropriate to the role they are fulfilling and the context in which they are working.” (Department for Education, 2013b, para. 14, p.7)*

Fuller’s (1969) three stage model, Table 2.14, can be used to describe teacher development. The model is based on the concerns of teachers and

how their concerns change as the teacher develops and can be used in research on teacher preparation and professional development (Conway & Clark, 2003). Zeichner & Teitlebaum (1982) categorise Fuller's model under the reflective paradigm.

Table 2.14 Fuller's concerns model of teacher development

Stage One	Pre-teaching Phase: Non-Concern	Concerns about self
Stage Two	Early Teaching Phase: Concern with Self	Concerns about Self as Teacher
Stage Three	Late Teaching Phase: Concern with Pupils	Concerns about Pupils

Source: Fuller (1969), Fuller, Parsons and Watkins (1974), Fuller and Bown (1975)

In stage one, teachers are concerned with their adequacy and survival; class control, being liked by pupils, being observed and evaluated. These concerns are mainly held by pre-service teachers. In stage two teachers concerns have moved onto the limitations and frustrations in the teaching situation and are more evident in in-service teachers. The final stage in the development is for concerns about pupils; their needs, learning and tailoring content to pupils. Stage three concerns are considered more mature and sought after than the earlier stages (Fuller & Bown, 1975; Veenman, 1984).

### 2.6.5. Enquiring

The enquiring model is based on teachers actively using research methods to develop their teaching ability. Although the reflective model may appear to use the same framework of continual testing of ideas and improvement it is not research. The enquiring model is associated with action research (Menter, 2010). Action research is a method of educational research that teachers can adopt as a tool for change (Cohen et al., 2007).

In this paradigm it is not the content and pedagogical knowledge that is taught to the teacher but the skills to be able to conduct critical research. Through this teachers will gain mastery of their subject (Zeichner, 1983). Zeichner and Teitlebaum (1982) suggest that Van Manen's (1977) levels of reflectivity can be used to model levels of enquiring. Teacher learning and development through this method is found in Masters level courses for teachers where they would be expected to undertake small individual research projects.

### 2.6.6. Transformative

The transformative paradigm extends the responsibilities of a teacher beyond transmitting knowledge and expects teachers to contribute to social change by addressing inequalities in society (Menter, 2010).

## 2.7. Initial Teacher Training

### 2.7.1. Standards

The statutory teaching standards apply to teachers across all subjects. A timeline for the introduction of statutory standards is presented in Table 2.15. Alongside the development of the general teaching standards and guidelines for ITT there have been some unique developments in standards and guidance for specifically D&T trainee teachers.

Table 2.15 Statutory teaching standards for ITT

Year	Standards Introduced
1992	Circular 9/92
1998	Circular 4/98
2002	New teaching standards and requirements to enter initial teacher training are introduced (Department for Education and Skills & Teacher Training Agency, 2003)
2007	(Revised 2008) Updates to Teacher standards (Training and Development Agency for Schools, 2008)
2011	(Updated 2013) Updates to teacher standards (Department for Education, 2013b)

Teaching standards and requirements for initial teacher training begin with the introduction of Circular 9/92, which introduced compulsory school based training and competence assessment (Gregory & Nicholson, 1994).

In 1997 the D&T Association and the Teacher Training Agency (TTA), the agency responsible for teacher training at that time, raised concerns with the subject knowledge of D&T trainee teachers (Design and Technology Association, Teacher Training Agency, & Unilever, 1997).

In 2002 the standards for the requirements for ITT were introduced in Qualifying to teach (Department for Education and Skills & Teacher Training Agency, 2003). These were not subject specific.

In response to the new ITT standards and the concerns raised on D&T ITT a thorough set of minimum competences specifically for D&T secondary school



teachers was created by the D&T Association (2003). All secondary school D&T teachers would be expected to meet the Core competences in the context of D&T. The competences of the 4 specialist fields of Electronics and Communications Technology, Food Technology, Materials Technology and Textiles Technology were divided into KS3 competences and KS4 and beyond competences. The D&T Association's minimum competences were adopted and used by ITT providers in conjunction with the statutory requirements for D&T ITT. They were however open to interpretation (Martin, 2008). These subject specific minimum competences were updated in 2010 (Design and Technology Association, 2010).

The 2007 teacher professional standards, for England published by the Training and Development Agency for Schools (TDA) had clearly defined levels of development and competencies associated with each level (Training and Development Agency for Schools, 2007, 2008). These professional levels have now been superseded by the 2011 Teaching Standards (Department for Education, 2013b) which do not follow a strict effective progression framework.

### **2.7.2. Routes to Qualified Teacher Status**

It is particularly interesting to note that the beginning of a teacher's education has been named Initial Teacher Training, not Initial Teacher Education (Benson, 2009). Pre-service teachers are called trainees not students, to emphasise the amount of work-based training that occurs to prepare teachers (Banks, 2009a).

There are a diverse range of ways to study to become a technology teacher in the UK (Williams, 2009a):

- Two Year Diploma of Education,
- Four Year Bachelor of Education,
- Four Year Double Degree,
- Two Year Bachelor of Teaching or Bachelor of Education,
- One Year Graduate Certificate or Diploma of Education,
- Two Year Graduate Diploma of Education,
- One and Two Year Master of Education Degree.

Each of the routes to Qualified Teacher Status (QTS) takes varying amounts of time. The amount of time spent in schools on multiple teaching practices is always significant as this was governed by Circular 9/92 and its successors. However, the amount of time spent outside of school learning subject knowledge and pedagogic theory greatly differs. The undergraduate routes to teaching will also contain all the necessary subject knowledge (Williams, 2009a), while the one year postgraduate courses have very little time for subject knowledge development and work on the suitability of prior qualifications (Atkinson, 2011; Banks, 1997; Benson, 2009). Although the time spent on aspects is different across courses, the content itself is similar (Owen-Jackson & Fasciato, 2012).

Atkinson, Knox and Hardy (2011) assessed the differences between undergraduate and postgraduate training routes. They found that the undergraduate route provided slightly better teachers than the postgraduate route. Following postgraduate trainees should improve their teaching skills, subject knowledge and belief in CPD.

Wooff, Hughes and Bell (2011) suggest the inclusion of additional discrete elements focused on STEM into ITT, as teachers require direction and a clear definition to understand how to implement STEM as an important part of the curriculum. Gibson (2012) achieved this through STEM industrial experience within the ITT programme.

## **2.8. Continuing Professional Development**

As laid out in the teaching standards, professional development is an activity that all teachers should participate in (Department for Education, 2013b). Once teachers in England have passed their initial teacher training, gained QTS and survived their newly qualified teacher (NQT) year, professional development is their route to further knowledge and skill improvement and career progression.

To progress beyond their pre ITT qualification knowledge teachers need to participate in CPD. There have been activities globally to improve the technology knowledge of teachers. These have utilised different delivery methods such as regional centres providing short courses (Davies & Rutland,

2013), university accredited certificates (Gumbo et al., 2012) and graduate courses (Barak, 2011), resource websites (Fox-turnbull, O’Sullivan, & Pearce, 2011) and professional development assessment tools (Chikasanda, Williams, Otrrel-cass, & Jones, 2011). Banks (2009b) identified that a teacher’s personal subject construct has an effect on their response to a professional development activity. A model of professional development of teachers is given by Desimone (2009), and is shown in Figure 2.4

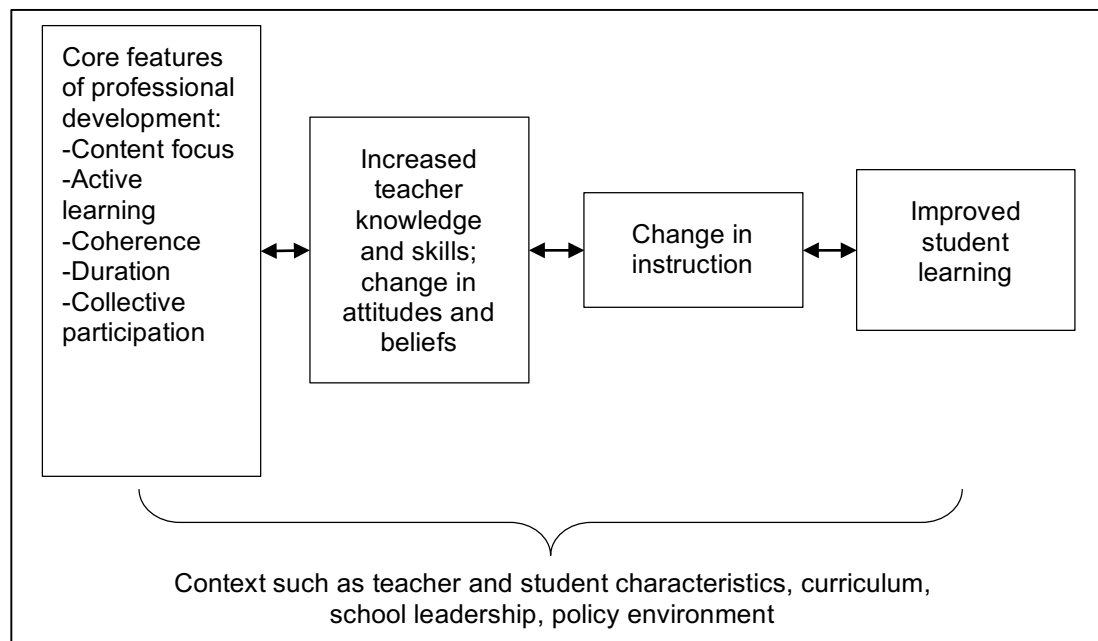


Figure 2.4 Proposed core conceptual framework for studying the effects of professional development on teachers and students (Desimone, 2009, p. 185, Fig. 1)

## 2.9. Chapter Summary and Implications for this Research

This literature review has identified, reviewed and explored the knowledge and skill domains that are critical to effective teaching technology education as identified in the models of Shulman (1987), Banks *et al.*(1999), Turner-Bisset (1999) and Mishra and Koehler (2006). The seven knowledge domains: content and subject knowledge, pedagogic knowledge, pedagogical content knowledge, curriculum knowledge, school knowledge, personal subject construct and beliefs and technological knowledge can be used as a framework for qualitative analysis of teachers throughout this research.

A unique problem with content knowledge, which would in turn effect pedagogic content and technological pedagogical content knowledge was identified as the breadth of subject knowledge required in D&T. Limited

improvements to subject knowledge takes place during ITT (Atkinson, 2011; Banks, 1997; Benson, 2009) or during service (Micklewright et al., 2014; Ofsted, 2011b) resulting in a high level of importance placed on the subject knowledge possessed by the teacher before teacher training. Teachers in England require a degree, or equivalent qualification, in order to train (SI 2003/1662, 2003). It is therefore worth investigating the prior qualifications of D&T trainee and qualified teachers to assess if they suitably prepare teachers for technology education.

The literature shows that teachers currently in school have developed a belief of how D&T should be taught from their prior experience of D&T as a pupil (Pajares, 1992), from other teachers and mentors (Banks et al., 2004) and through exam boards (Atkinson, 2000b). These beliefs are interconnected with school and curriculum knowledge. These beliefs and the curriculum they create are resistant to change (Dow, 2006; Drageset, 2010; Lewis et al., 2005). Without a sufficient motivational reason to change this belief system, worsened by the apparent high assessment scores given to work, the cycle of teachers habitually running the same tired projects will continue (Atkinson, 2000b; Barlex & Rutland, 2008; Zanker, 2005). It has been shown that beliefs can be effected through education, without deliberate intervention to improve knowledge of technology teacher find themselves in the current situation and adopt the school's old belief system. These beliefs dictate the content of technology education and the restrictive and unimaginative project given to pupil can be used to explain the effect on pupil numbers studying D&T.

The literature on the knowledge possessed by D&T teachers indicates that there is a potential cause for concern with the technology aspect of all these knowledge domains. With all the changes to the curriculum over its history and especially with the recent revisions to KS3 and KS4 it is unclear whether teachers have been able to keep up with the changes in demand; or if suitable opportunities or resources are available for teachers to assist them with these changes.

The paradigms identified in the works of Zeichner (1983), Feiman-Nemser (1990), Zeichner and Liston (1990) and Menter (2010) provide different approaches to teacher education and its assessment. The mixed methods

approach undertaken in this research utilises the different epistemological viewpoints of the Effective and Reflective paradigms. By assessing teacher education from these different viewpoints a more complete picture of the situation can be created. The Effective and Reflective paradigms use quantitative methods such as competency assessment and qualitative methods respectively to assess teacher development.

Teacher development occurs in two distinctive phases; ITT and CPD. These two circumstances for improving teacher knowledge focus on different areas of knowledge. With ITT dominant on pedagogical knowledge and skills it is essential that teachers participate in CPD programmes in the other knowledge categories. However the specific needs of teachers' technology CPD requirements remain unknown. The types of courses, content and which knowledge or skills that needs to be developed for teachers to improve their ability to deliver technology education are to be explored.

### **3. Demographic analysis of D&T Teachers**

#### **3.1. Introduction**

The literature in Chapter 2 identified the range of knowledge types that a teacher must possess to be effective. The literature review suggests that teachers already possess the majority of their content knowledge before they train to be a teacher. The ITT programme is designed to provide pedagogic knowledge and develop pedagogical content knowledge and curriculum knowledge. This puts a significant importance on the knowledge and skills possessed by a teacher before they begin their ITT.

In order to investigate the subject/content knowledge that teachers possess before becoming a teacher this initial study provides a demographic descriptive analysis of a sample of trainee teachers at the start of their PGCE D&T programme.

##### **3.1.1. Aims of the study**

The specific aims of this study were to:

- Determine the subject knowledge background of D&T teachers
- Discuss the effects of this on University based PGCE ITT programmes.

#### **3.2. Methods**

##### **3.2.1. Design**

This study is a quantitative descriptive analysis of D&T PGCE trainees. From a positivist viewpoint the analysis of results in this chapter will discuss the evidence from a statistical sample and from this draw inferences about the population of D&T teachers. This study analysed all available data of thirteen cohorts of PGCE Design and Technology trainees, studying at Loughborough University between the academic years 2000-2001 and 2013-2014 inclusive. The sample contains a total of 341 trainees across all years.

##### **3.2.2. Sampling**

To determine the sample size necessary for this study, a power calculation was undertaken. Population data was available from the Department for Education (2015b). Only the academic years 2008-2009 to 2013-2014 were

available in the data collected and the data set from the ITT trainee number census to compare. The figures used are shown in Table 3.1. These years have been used to estimate the required sample size and confidence level for this sample. The population data from the Department for Education was for all technology ITTs. Historically the category of technology ITT was technology subjects but also included were the subjects of ICT, Computer Science and Business Studies. Although this population is greater than just D&T trainee teachers is it the most accurate estimated population of D&T available over a significant number of years.

Table 3.1 Data used for sample power estimation

<b>Starting year of ITT</b>	<b>Sample<sup>1</sup></b>	<b>Population<sup>2</sup></b>
2008	25	2680
2009	31	3100
2010	25	2940
2011	18	1970
2012	14	1390
2013	9	952
<b>Total</b>	<b>122</b>	<b>13032</b>

Note: <sup>1</sup>Sample is the number of Loughborough University PGCE trainees each year.

<sup>2</sup>Population of all Technology ITT, Historically Technology also includes ICT, Computer Science and Business Studies (Department for Education, 2015b).

The total population for the years was 13,032. Sample size required for this population was calculated using equation 3.1 (Krejcie & Morgan, 1970).

$$s = X^2NP(1 - P) \div d^2(N - 1) + X^2P(1 - P)$$

$s$  = required sample size

$X^2$  = the table value of chi-square for 1 degree of freedom at the desired confidence level

$N$  = the population size

$P$  = the population proportion (assumed to be .50 since this would prove the maximum sample size)

$d$  = the degree of accuracy expressed as a proportion

3.1

The sample size required was calculated as 95 (confidence interval 10% at 95% confidence level). The collected sample, over the comparable years,

consisted of 122 and was therefore greater than the required sample size and is consequently acceptable to use as a representation of the population at 95% confidence level. The collected sample size of 122 gives a confidence interval of 8.83% at 95% confidence level.

### 3.2.3. Procedure

#### Data Categorisation

The raw data was previously collected by Loughborough University and the D&T PGCE programme director between 2000 and 2013. The variables collected were the Name, Age, Degree, Higher Education Institute (HEI) Degree was from and Result of first degree of each trainee enrolled on the PGCE programme. The data was initially anonymised to protect the identity of those involved. Using the name of degree and institute it was gained from, the variable Degree Group was created and degrees were sorted into the Joint Academic Coding System (JACS) categories used by the Higher Education Statistics Agency (HESA) and the Universities and Colleges Admissions Service (UCAS). Not all JACS categories were necessary due to the alignment of degree subjects to D&T ITT courses. Data on the degree were split into Degree Type and Degree Classification. The variables used in the subsequent analysis are listed in Table 3.2.

Table 3.2 Variables

Variable	Values
Year of PGCE start	Scale Data
Age	Scale Data
Degree Classification	First Class, Second Upper Class, Second Lower Class, Third Class.
Subject Group	Agriculture & related subjects, Architecture, building & planning, Business & administrative studies, Creative arts & design, Engineering & technology, Librarianship & information science, Physical sciences.
Degree Type	BA, BDes, BEng, BSc, CGLI, HNC, HND, MA, MDes, MEng.

#### Missing Data

There are missing values in the data collected and used in this study, summarised in Table 3.3. Missing data may introduce bias and increase Type I and Type II errors (Collins, Schafer, & Kam, 2001). It is therefore important to identify the types of missing data and what solutions exist to reduce problems associated to missing data (Wilkinson & Task Force on



Statistical Inference, 1999). Gelman and Hill (2006) and Scheffer (2002) list categories of missing data in statistical analysis and describe how each must be addressed:

- Missingness completely at random (MCAR). The probability of missingness is equal for all variables and therefore cases with missing data can be discounted without introducing bias.
- Missingness at random (MAR). Although not truly random the significance of the missingness can be tested in comparison to a variable with no missing cases. Single or Multiple Imputation methods can be used for missing values.
- Missingness not at random (MNAR). These cases of missingness can depend on unobserved predictors or depend on the missing value itself. Cases of MNAR cannot be ignored. MNAR missing values should be imputed using Multiple Imputation methods at missingness levels of less than 25%.

Data imputation is the process of using plausible values to fill in missing data (Schafer, 1999). Imputation of missing data minimises bias and allows the use of data that has been collected. However the imputed data is not real and the type of imputation used can reduce variance in data (Scheffer, 2002). The first stage was determining the amount of missing data. The descriptive statistics for the missing data are presented in Table 3.3. There are no missing data for the variables Age and Subject Group. The variable Degree Classification and Degree Type have over 5% of cases with missing values. These variables have been tested for MCAR and MAR to determine if data can be discounted listwise, imputed or if other action is required.

The variables were tested for MCAR using Little's MCAR test (IBM, 2014; Little, 1988), see Table 3.3 ( $\chi^2(8) = 29.966, p = .000$ ). The test statistic is significant ( $p < 0.001$ ) and therefore the null hypothesis ( $H_0: \mu = \text{MCAR}$ ) can be rejected. The missing data are not MCAR.

Table 3.3 Missing data descriptive statistics and estimated means

Variables	N	Missing		Estimated Means		
		Count	Percent	Listwise	All Values	EM <sup>a</sup>
Age	341	0	0.0	25.21	25.32	25.32
Degree Classification	291	50	14.7	2.41	2.43	2.41
Subject Group	341	0	0.0	4.04	4.08	4.08
Degree Type	321	20	5.9	1.75	1.92	1.92

a. Little's MCAR test: Chi-Square = 29.966, DF = 8, Sig. = .000

Table 3.3 shows a difference in means between complete cases and listwise deletion of cases. As the missing data are not MCAR the deleting of cases listwise would introduce bias to the data and also reduce the statistical power of the data through the creation of a smaller sample.

To determine if data imputation was suitable the variables were tested to determine if they were MAR. Table 3.4 shows the results of Separate Variance t Tests to determine if there are any significant differences between complete and missing cases. There is a significant difference ( $t(52.6) = -2.9$ ,  $p = .006$ ) on Degree Classification for the variable Degree Type. There is a significant difference ( $t(22.4) = -2.5$ ,  $p = 0.019$ ) on Degree Type for the variable Subject Group. As there is a relationship missing variables in the data the missing cases can be assumed to be MAR.

Table 3.4 Separate Variance t Tests

	Degree Classification			Degree Type		
	t	df	p	t	df	p
Age	-0.6	57	0.528	-0.1	20.7	0.906
Degree Classification	.	.	.	-2	21.9	0.062
Subject Group	-1.1	59.1	0.273	-2.5	22.4	.019*
Degree Type	-2.9	52.6	.006**	.	.	.

Significant at \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed. \*\*\* $p < .001$ , two-tailed.

As a final check for the MAR assumption the correlation of MAR variables are shown in Table 3.5. This shows that Degree Type and Degree Classification and Degree Type and Subject Group are missing often together.

Table 3.5 Variable Correlations

		Degree Classification	Degree Type	Subject Group
Degree Classification	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	291		
Degree Type	Pearson Correlation	-.152*	1	
	Sig. (2-tailed)	.012		
	N	272	321	
Subject Group	Pearson Correlation	-.006	.200***	1
	Sig. (2-tailed)	.919	.000	
	N	291	321	341

Significant at \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed. \*\*\* $p < .001$ , two-tailed.

Following the assumption for MAR data the cases with missing data will have their missing values imputed. Multiple imputation was selected as the most appropriate method as it addresses the flaws of single imputation (Little & Rubin, 2002; Rubin, 1987). Multiple imputation produces unbiased estimates that reflect sampling variability (Little & Rubin, 2002; Wayman, 2003). The Multiple imputation methods within IBM SPSS Statistics 22 were used for data imputation and the imputed data was used in section 3.3.

### 3.2.4. Analysis

IBM SPSS Statistics Version 22 was used to code the data variables and to perform the data imputation task and statistical analysis.

Descriptive statistics were then calculated for the following variables

1. Prior Qualification Subject and Type
2. Trainee Numbers
3. Age
4. Degree Classification
5. Prior Qualification Subject and Type

## 3.3. Results

### 3.3.1. Trainee Numbers

The number of trainees enrolled on the D&T PGCE programme at Loughborough University (LU) each academic year between 2000 and 2013 are shown in Figure 3.1. Total number of trainees across all years was 341. Alongside the collected data are national statistics published by the Department for Education (2015b) gathered from the National College of

Teaching and Leadership (NCTL) Initial Teacher Training Census. The two data series used from the Department for Education are the total population of all secondary ITT trainees between 2004 and 2013 and the population of all technology ITT between 2008 and 2013. The year range differences are due to available data.

A simple linear regression was calculated to model the change in trainee numbers by year. A significant regression equation was found ( $F(1, 14) = 13.542, p = .003, R^2 = .530, B = -1.475, \beta = -.728$ ). This shows a negative trend.

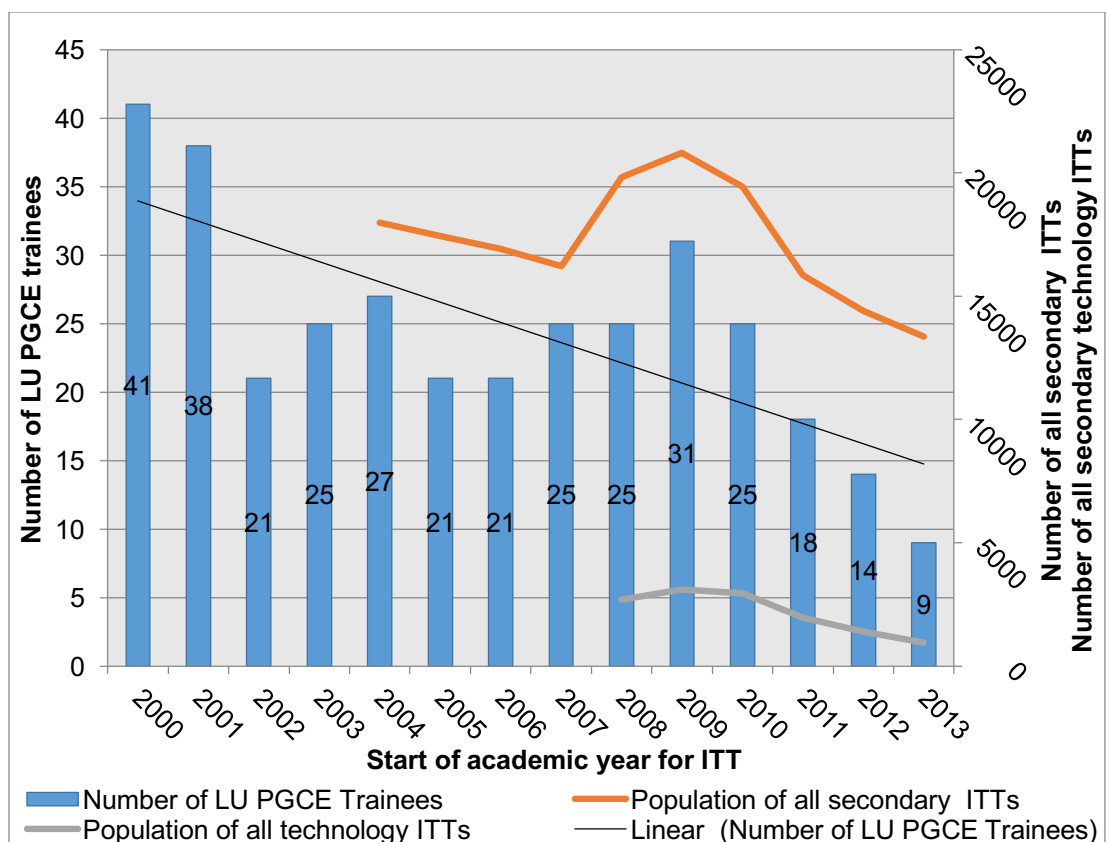


Figure 3.1 Number of Loughborough University D&T PGCE ITT trainees by Year compared to national technology and total ITT figures (Department for Education, 2015b)

### 3.3.2. Age

Descriptive frequency statistics for age are shown in Table 3.6. The distribution of the age of the PGCE students is shown in Figure 3.2. The cumulative age distribution is also presented.

Table 3.6 Descriptive Frequency Statistics for Age of students starting PGCE

N	Mean	Median	Mode	Range	Minimum	Maximum
341	25.32	23.00	21	35	20	55

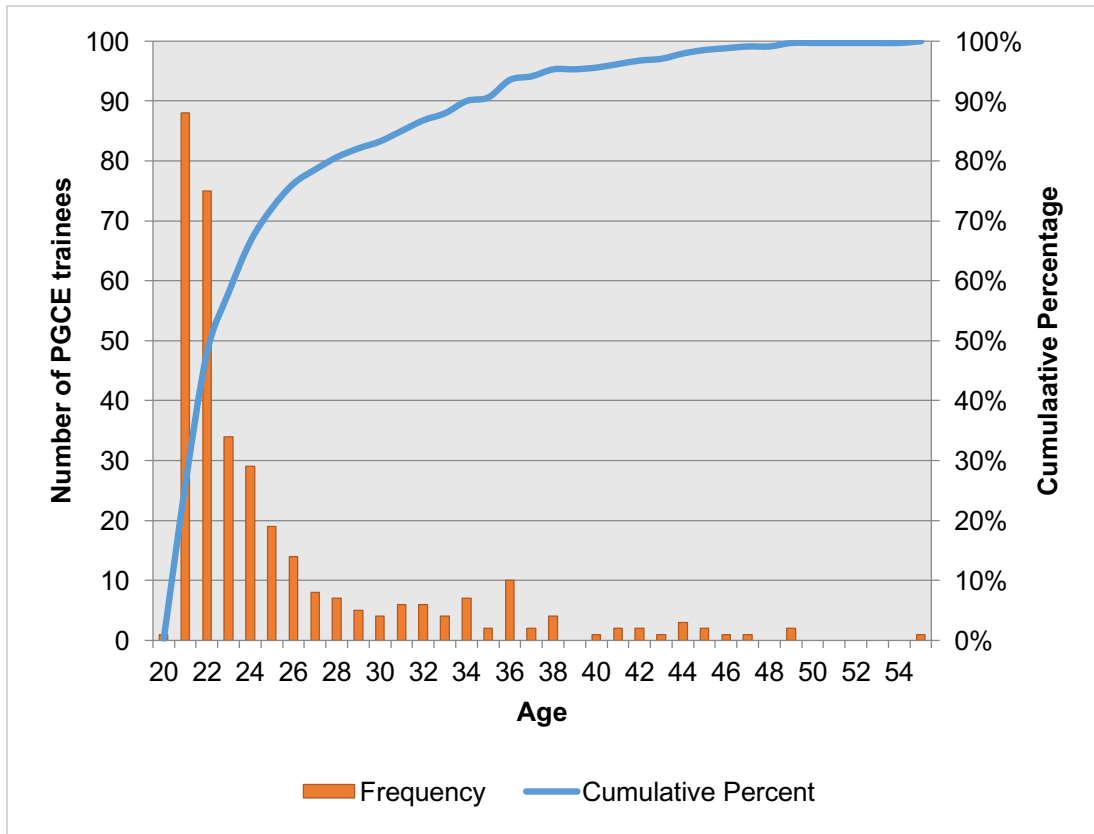


Figure 3.2 Age distribution of PGCE trainees

### 3.3.3. Degree Classification

To classify the quality of a degree the category of good degree grade is used, this is made up of those gaining either a First Class (1) or Upper Second Class (2:1) (Bratti, 2002; Naylor & Smith, 2004; Smith & Naylor, 2005; Smithers, Robinson, & Coughlan, 2013). The percentage of each cohort of PGCE trainees with a good degree is shown in Figure 3.3. Figure 3.3 also presents the national trend data for all ITT. Data for national statistics on all secondary ITT entrants have been taken from Smithers et al. (2013). Across all years the distribution was 51.61% (n = 176, 95% CI [42.78%, 60.44%]) trainees with a good first degree.

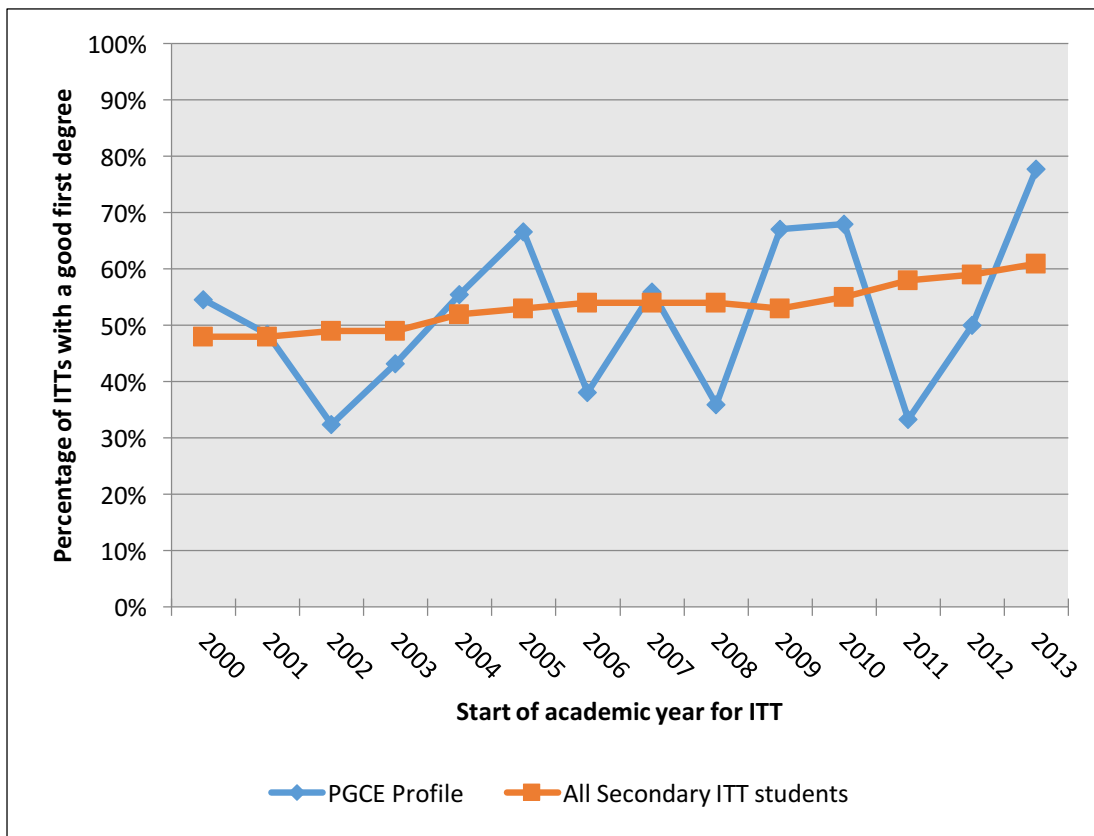


Figure 3.3 Percentage of ITT students with good first degree grade by year

### 3.3.4. Prior Qualification Subject and Type

The subject of the prior qualification held by D&T trainees is shown in Figure 3.4. The majority of D&T teachers trained with a prior qualification in creative art and design subjects 81.23% (n = 277, 95% CI [72.40%, 90.06%]).

Within the collected data were subjects coded as creative arts and design (n=106). Figure 3.5 shows the type of qualifications held by D&T trainees to reveal more detail about the type of creative arts and design subjects.

66.39% (n = 226, 95% CI [57.56%, 75.22%]) of D&T trainees studied a BA degree in creative art and design.

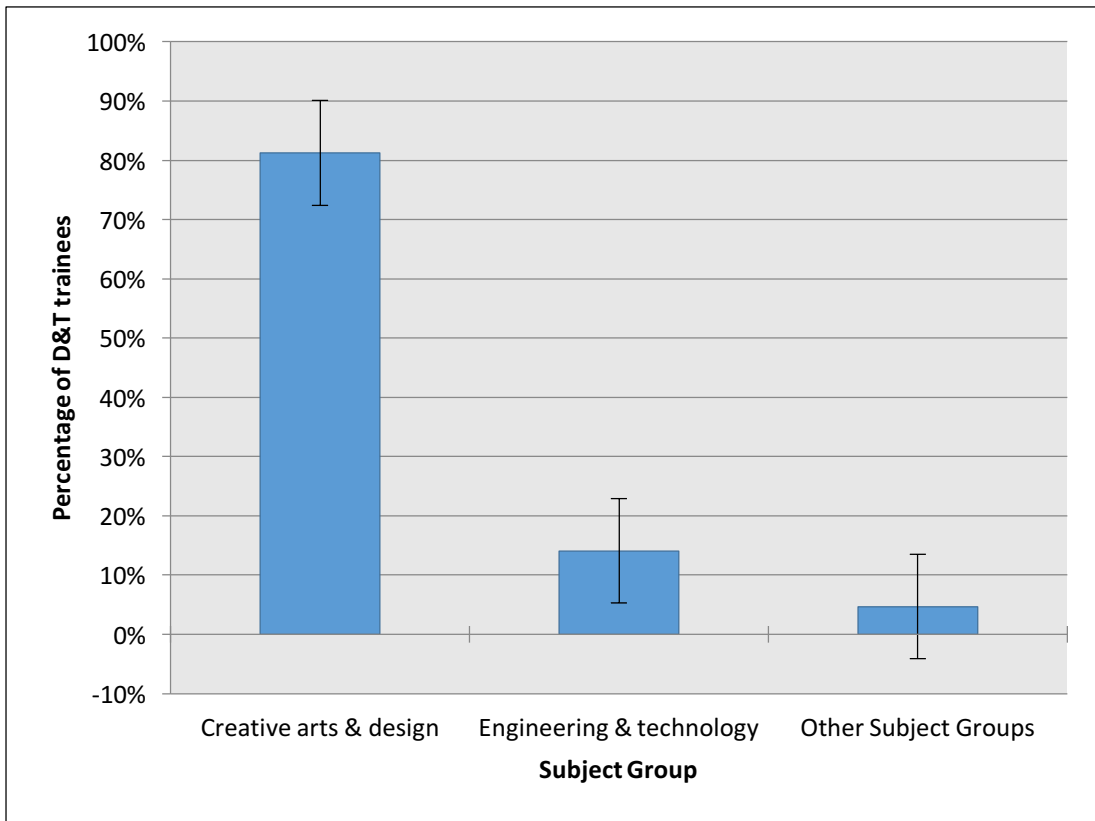


Figure 3.4 Subject area of qualification held prior to D&T ITT  
Other Subject Groups includes architecture, building & planning, business & administrative studies, agriculture & related subjects, librarianship & information science and physical sciences.

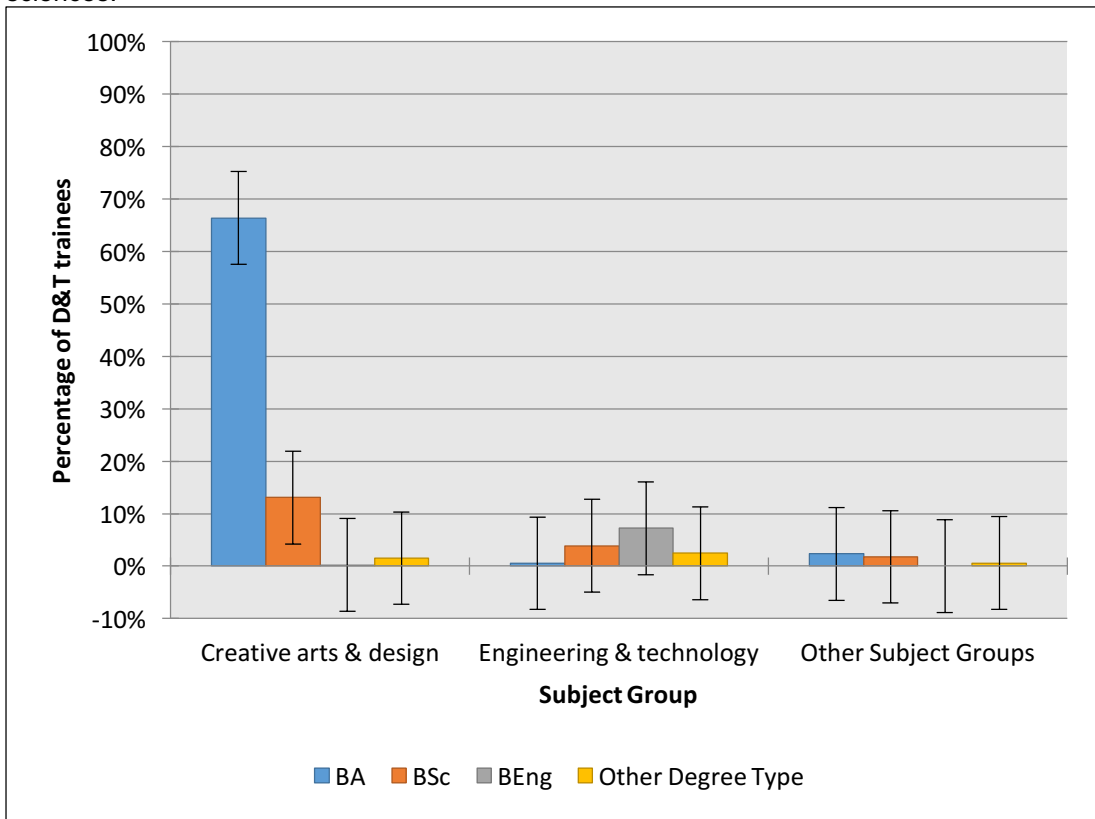


Figure 3.5 Type of qualification held prior to D&T ITT (n = 341)  
Other Subject Groups includes architecture, building & planning, business & administrative studies, agriculture & related subjects, librarianship & information science and physical sciences.  
Other Degree Types include CGLI, HNC, HND, BDes, MA, MDes, MEng.

### 3.4. Discussion

#### 3.4.1. Content and Subject Knowledge

The literature review in Chapter 2 identified the need to investigate the subject knowledge of teachers before they entered the profession. It was found that the necessary qualification (degree) to enter ITT and gain QTS is the primary source of teachers' subject knowledge. The range of suitable qualifications to become a D&T teacher covers all of the Engineering and Technology degree subjects. The list would suggest that Engineering, Technologies and Architecture, Building and Planning students are training to be D&T teachers. These degrees would be desirable as they would provide teachers with the necessary technology subject knowledge they require. However, the results identified that the distribution of prior qualifications was skewed towards creative arts and design, 81.23% (n = 277, 95% CI [72.40%, 90.06%]).

The results in Figure 3.4 and Figure 3.5 show the subject of the degree or equivalent qualification held by prospective teachers. The majority of trainees, 66.39% (n = 226, 95% CI [57.56%, 75.22%]), held a Bachelor of Arts degree in a creative arts and design subject. Compared to 13.08% (n = 45, 95% CI [4.25%, 21.91%]) of trainees with a Bachelor of Science in creative arts and design. The percentage of trainees with qualifications in engineering and technology was 14.08% (n = 48, 95% CI [5.25%, 22.91%]).

This is a concern as the broadness and level of technology or technical skills development in a BA creative arts and design subject will be less than a BSc or BEng in engineering and technology subjects. For example, it would not be expected for an arts student to have knowledge of non-parametric CAD and CAM, mechanics, systems, electronics or many of the other technical areas of the D&T curriculum identified in Chapter 1. It is therefore suggested that if this majority of D&T teachers with a creative arts and design background do not have the necessary technology subject knowledge then this will contribute to the decline of pupils studying technology subjects that was identified in Chapter 1.

Lewis (1995) recognises that prior qualifications are not the only factor used to assess the alignment of a trainee to their ITT programme and that they may have other experience that would make them suitable. At the institution



the sample trained, the D&T PGCE ITT programme was rated outstanding following its latest inspection (Mann & Ofsted, 2011). Therefore, all the trainees have been assessed to begin their ITT following the statutory guidance and the D&T Association Minimum Competences for Trainees to Teach Design and Technology in Secondary Schools. At the sample institution the trainees would be required to demonstrate all of the core competences which include technical skills and competence in two subject knowledge specialist areas. One of these areas must be a KS4 level and above.

The overall quality of the prior degree held by teachers has been measured by the classification of degree and describing a good degree as a first or upper second class. The PGCE programme recruited applicants with qualification classifications in line with national levels. However, findings from Smithers et al.,(2013) showed that STEM ITT subjects attract the least qualified graduates and it was claimed that subject knowledge measured by degree result is more important in these areas.

The starting age of D&T ITT students does not indicate that students would have gained significant technical experience through another career. Figure 3.2 shows that 48.09% (n = 164, 95% CI [39.26%, 56.92%]) of the ITT students were aged 22 or younger. At this age they would have only just completed their first degree and therefore would have little experience from other careers.

The PGCE programme in this study has produced qualified teachers in-line with all the statutory requirements and following the guidance of the D&T Association and Ofsted. The training standards appear to, unintentionally, bias the selection of teachers with design skills and knowledge over technology skills and knowledge. The lack of fundamental technological knowledge may be a contributory factor to account for performance of technology education in secondary schools. Without sufficient subject knowledge or awareness of technology it is likely that teaching in this area will be poor. The subject knowledge deficiency identified in this study can be used to explain the curriculum and project content issues identified in the Chapter 2 literature review.

It is not possible to form a definitive conclusion as to the performance of technology education from these data alone. It is therefore recommended that further research should explore the teaching of technology in schools in order to identify if this suspected issue does have an effect on teaching.

#### **3.4.2. University based PGCE ITT programmes**

The results show a gradual decline, approximately 1.5 students per year, in the number of students studying for a PGCE in D&T at this institution. This is in line with available national data showing a decline in the total number of technology teachers nationwide. For the academic years 2012/13, 2013/14 and 2014/15 D&T ITT only met 86%, 45% and 44% of its recruitment targets respectively (Department for Education, 2015b). Following the data collected for this study the D&T PGCE programme at Loughborough University was closed due to low student numbers. Caused by three factors; a decrease in applicants meeting the required prerequisite qualification and skills profile, the national decrease in students studying ITT (Department for Education, 2015b) and the government driven switch away from university led ITT created by an increase in the allocation of places to the schools direct scheme (Universities UK, 2013). Since 2011 the government's policy has increased emphasis on School Direct as the key route to QTS (Beauchamp, Clarke, Hulme, & Murray, 2013).

A reduction in university led ITT may have negative impact on the training of teachers. The educational research outputs from HEIs are directly fed into the content of their ITT programmes (BERA, 2014). This is a system of continual improvement that is unique to universities. As ITT in schools is a master and apprentice craft training model (Gove, 2010), higher education's ability to contribute intellectually to teacher education will be reduced (McNamara & Murray, 2013). Without university intervention schools will become reliant on their own existing knowledge and favoured practices. There would be no external training for teachers to develop new knowledge. There is potential to create a cycle of complacency. This problem could be exaggerated further by the absence of requirements for qualified teachers at academies and free schools in England. The reduction in numbers of trainees training now will have longer term impact in the number of skilled D&T teachers working in schools in the future.

### **3.4.3. Limitations**

The limitations of this study occur from the use of a singular source of data. Although a suitable sample size and acceptable confidence interval at 95% level were calculated there are still potential sources for bias within the data. All data in the study were generated from trainees at the same institution and analysis will therefore not be able to identify any potential differences between institutions. All data in the study was generated from trainees on a 1 year PGCE programme, and the analyses is therefore unable to identify any potential differences in results caused by alternative routes to QTS. The use of national statistics within the analysis and discussion are to check that the sample follows similar trends to the population on variables that are available. This is to ensure greater reliability on the analysis of the subject group variable.

### **3.5. Summary and Conclusions**

This study has investigated teachers at a critical point in their career. The content and subject knowledge possessed by a teacher as they begin their ITT has been identified as important from a review of the literature. This study has provided a more detailed description of the subject knowledge possessed by D&T teachers through the presentation and analysis of descriptive statistics for a D&T ITT programme. Previous works have described potential problems with D&T teacher technological subject knowledge (Banks, 1996b; Evans, 1998; Lewis, 1995) but they do not hypothesise the cause of these subject knowledge issues.

The detailed analysis of D&T teacher subject knowledge prior to teaching conducted in this study shows that 81% of D&T teachers have their prior qualification in creative arts and design and not in a technology subject. This is a key finding.

This study proposes that the misalignment between D&T teachers' prior knowledge and the technical subject knowledge required for D&T teaching is the cause for teacher inability to deliver technical content in schools. Further studies are required to validate this claim.

The suggested further work must first aim to validate if a background of non-technical subject knowledge leads to a lack of technology education performance and competence. This is to be achieved through measurement and analysis of the effect of subject knowledge on teaching in school, a more thorough analysis of teachers' knowledge through quantitative and qualitative triangulation methods and to determine what improvements to subject knowledge are required and how subject knowledge can be improved.

## **4. Exploring a Technology Project in School**

### **4.1. Introduction**

This chapter presents the findings from an exploratory study investigating teachers' use of resources in implementing a new school-based technology project. This study explored if the different teacher knowledge domains (Content and Subject Knowledge, Technological Knowledge, Pedagogical Knowledge, Pedagogical Content Knowledge, Curriculum Knowledge, School Knowledge and Personal Subject Construct) identified in the literature review can explain the behaviour and actions of teachers in adopting resources, developing new schemes of work and delivering projects, particularly the effects of suspected subject knowledge deficiencies identified in Chapter 3.

A new set of resources were developed by the researcher for teachers' use in the study. Teachers adopted and delivered the resources in their classrooms. The intended purpose of the resources was to teach technology areas of the curriculum such as CAD/CAM manufacturing using laser cutters, gear mechanisms and designs that required the application of mathematics and science knowledge.

#### **4.1.1. Aims of the study**

The specific aims of this study were to:

- Develop a technological project using appropriate pedagogic methods to teach mechanical systems by taking advantage of classroom CAM technology such as laser cutting.
- Determine how the teacher knowledge and skill domains identified in the literature review affect the adoption of new technology curriculum resources within secondary schools.

### **4.2. Method**

#### **4.2.1. New project resources**

A Laser Made Mechanical Timer project was developed for teachers and KS3 pupils studying D&T. This was informed by what students should

achieve in the National Curriculum<sup>3</sup> (Qualifications and Curriculum Authority, 2007), see Table 4.1, and what teachers should be able to teach from the D&T Association Minimum Competences for Trainees to Teacher Design and Technology in Secondary Schools (Design and Technology Association, 2010), see Table 4.2. In addition, the literature on best practices for delivering technology projects was reviewed.

The review of literature in Chapter 2 identified problems in current teaching practice, such as the continued use of out of date non-technological projects (Barlex & Rutland, 2008; Lewis et al., 2005; Zanker, 2005) and the reliance on exam board assessment models (Atkinson, 2000b; Banks, 2009b; Lewis, 2003). To assist the development of a new project, existing international best practices were reviewed to understand approaches to technology teaching. These best practices were drawn from published literature on the topic of best practices in technology education and through Ofsted good practice examples. Both the content and teaching methods used in the best practices informed the creation of a project entitled the Laser Made Mechanical Timer project.

The review of international best practices included specific schemes of work such as the history of technology in Scotland (Pryde, 2007), electronics in Australia (Cox, 2007), power and energy in the USA (Kastl, 2007), CAD in England (Ofsted, 2011a). It also included an innovative industrially related curriculum in England (Ofsted, 2012).

The review of best practice revealed common themes. One common feature of best practice was the use of an authentic and appropriate context. The ability to ground learning in real life contexts can separate the technology in D&T from Science and Mathematics (McCormick, 2004). People perform better in tasks that have a context they can relate to (Dreyfus & Dreyfus, 1980). The examples included contexts that were situated in historical technology sites (Pryde, 2007), from industrial projects (Ofsted, 2012) or using industrial tools (Ofsted, 2011a).

Another feature of best practice was the high level of subject knowledge that is taught. Technology projects identified contained the design of products that use or transfer energy i.e. working machines (Kastl, 2007; Pryde, 2007).

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<sup>3</sup> 2007 National Curriculum

This involved understanding the science behind the design and performing some level of calculation (Cox, 2007). Pupils were taught subject knowledge of materials science to learn about material properties and how they can select appropriate materials (Cox, 2007; Ofsted, 2012). Learning expanded from and developed upon the fundamentals taught earlier in the curriculum (Ofsted, 2012) and pupils gained transferrable knowledge and skills (Kastl, 2007).

The process of iterative design through modelling also appeared (Cox, 2007; Ofsted, 2011a). The iterative design process more closely reflects the reality of product and technology design as it is the process used by professional designers (Kimbell, Stables, & Sprake, 2002). Iterative design is an opportunity for D&T that creates a purposeful, rigorous and practical subject (Choulerton, 2015).

A review of best practice by de Vries (2007) identified the characteristics of good practice in technology education. The characteristics relevant to this work are:

- The synthesis of different content dimensions: procedural and conceptual, knowing how and knowing that, technological learning and learning about technology.
- Making pupils acquainted with the fact that different design problems require different strategies.
- Dealing effectively with the interests of the relevant stakeholders in technology education.
- Influencing attitudes by making the problems as realistic as possible, making students work in groups, being an understanding and passionate teacher, creating interdisciplinary and energizing learning environments.
- Stimulating motivation by actively engaging pupils and students in authentic learning (de Vries, 2007, pp. 8–9).

The Laser Made Mechanical Timer project consisted of a set of resources for pupils and teachers for a curriculum lesson based scheme of work. The project utilised laser manufacturing techniques to enable pupils to design, manufacture, assemble, analyse and investigate their own mechanical timing mechanism.

The project was intended to be developed into a scheme of work that addressed the lack of technology focus in D&T. This study explored the teaching of technology using a laser cutting project as an example and, in doing so, challenges the work for which lasers are most frequently used. Examples of current laser cutter use, published by the D&T Association, are using the laser to produce boxes (Berrill, 2011) or being used to produce jewellery (Elderton, 2012). These examples are evidence of laser cutters being used to improve the aesthetic qualities of products. The Laser Made Mechanical Timer project extended beyond the typical project examples of Berrill and Elderton and used the technology to its full potential in manufacturing functional components. This allowed pupils to manufacture their own technology products providing the context to learn the theoretical subject knowledge.

The provided designs would demonstrate the advanced use of laser cutting equipment to pupils. The project also required pupils to apply their mathematics knowledge during the design process by calculating critical components performance and using the scientific process and their science knowledge to investigate, analyse and explain the functionality of the mechanical system.

The Laser Made Mechanical Timer project was developed with an appreciation of the modern D&T classroom environment and utilised existing classroom facilities. Figure 4.1 shows the features described on an exploded diagram of the design.

- Materials were selected to be affordable and typically available in schools. Thicknesses were suitable for lower-power school laser cutters while still maintaining performance.
- The machined bushes and roller bearing units found in traditional clockwork mechanism were replaced with paperclip or panel pin needle bearings. These are significantly cheaper and easier to produce yet appropriate performance is maintained. The corresponding laser drilled holes in Medium Density Fibreboard (MDF) have large internal carbon deposits from the vaporisation process, this acts as a dry lubricant aiding bearing performance.



- The amount of required parts in the design were reduced. This reduces assembly time, material costs and cutting time. This involves creative features such as the combination of pendulum and escapement pallets which removes the need for multiple bearing parts, separate pendulum detachment and the crutch mechanism. Although the removal of these parts reduces the accuracy of the pendulum motion it will still give satisfactory performance and the significant reduction in complexity will benefit pupils.
- Laser cutting of the parts allows for parts to be efficiently nested into a smaller sheet of material and the supplied CAD files only require a small 450x250mm piece of MDF suitable for school laser cutters and school budgets.
- The slot and pin methods are non-permanent allowing disassembly to correct any pupil mistakes. It also does not require the use of adhesives removing the risk of toxic chemical use in lessons.
- The incorporated thread forms on parts of the clock are a unique feature of this design, made possible by the small kerf width of laser cutting. They allow standard nuts to be used for fixing and for pendulum centre of gravity adjustment. The pendulum adjuster is a really simple mechanism feature that provides classroom experimental potential.
- Design for Assembly techniques have been used in the design of the mechanism. This technique has taken into account the need for alignment of the entire mechanism during assembly. The assembly process does not require any jigs or fixtures; this therefore increased the simplicity of the assembly process. Alignment and fixing was controlled by the cross sectional shape and features of the parts.

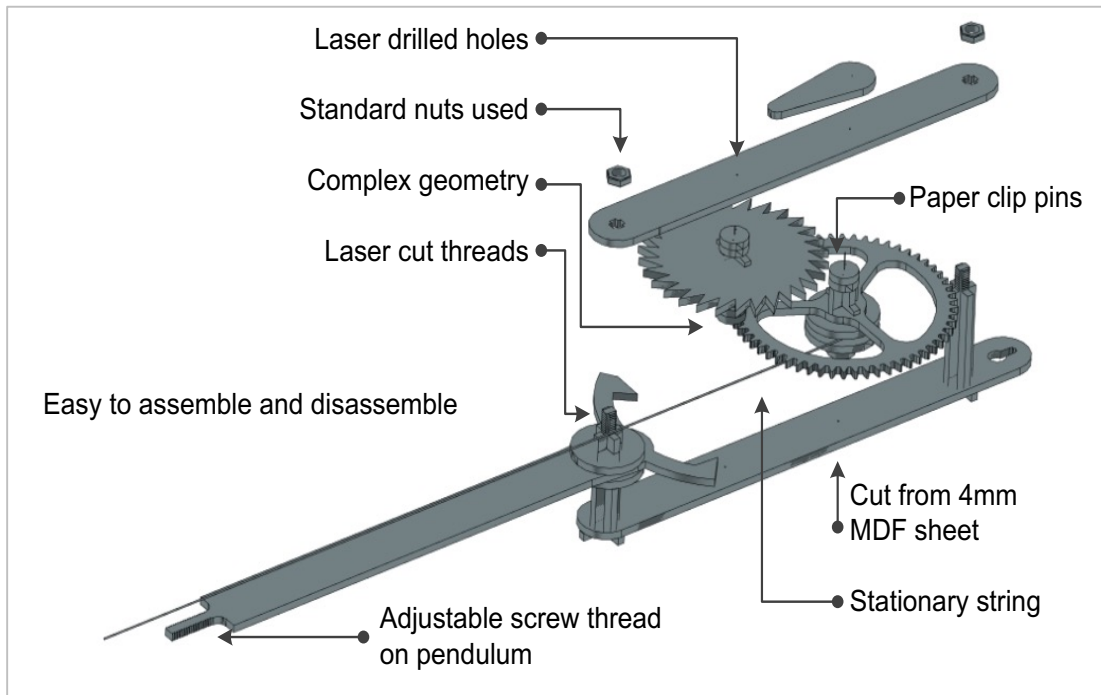


Figure 4.1 Exploded diagram of mechanism showing features suitable for schools

To enable pupils to manufacture their own mechanism using their school's laser cutter, the project provided pupils with a set of CAD files that contain the mechanism design. Figure 4.2 shows the CAD data provided to pupils. These files were provided in formats accessible by school CAD systems, such as Techsoft 2D Design files and the DXF format. Files were provided to suit commonly available school material thicknesses.

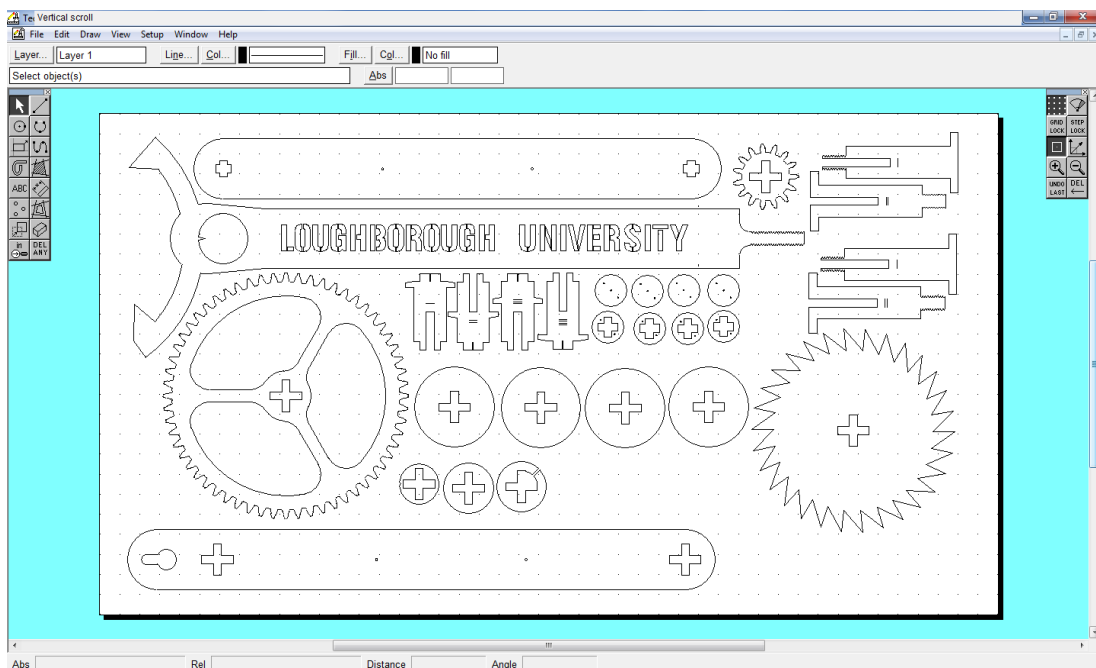


Figure 4.2 Timer cutting pattern in Techsoft 2D Design

To enable pupils to assemble all the parts into a working mechanical timer it was necessary to produce and provide an assembly guide. Agrawala et al., (2003) suggest the use of simultaneous planning and presentation, breaking down the hierarchy of parts and to produce step-by-step guides with structural and action diagrams. The assembly guide produced was a 13 page book which contains list of parts required, ensuring that pupils have everything they need to begin. Instructions directed pupils to manufacture the pins and then the assembly process was broken down into manageable sub-components with exploded diagrams, listed parts and step-by-step labelled illustrations. The assembly guide is shown in Appendix A -Laser Made Mechanical Timer Assembly Guide.

Table 4.1 D&T KS3 National Curriculum Range and Contents

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The study of making in resistant materials and textiles should include:

- j. a broad range of techniques, including handicraft skills and CAD/CAM, and how to use them to ensure consistency and precision when making single and multiple products
- k. the behaviour of structural elements in a variety of materials
- l. how to use materials, smart materials, technology and aesthetic qualities to design and make products of worth
- m. how to prepare and assemble components to achieve functional results.

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The study of making in systems and control should include:

- n. the practical application of systems and control in design proposals
- o. electrical, electronic, mechanical, microprocessor and computer control systems and how to use them effectively
- p. using systems and control to assemble subsystems into more complex systems
- q. feedback and how a variety of inputs can give rise to a variety of outputs.

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Source: (Qualifications and Curriculum Authority, 2007, p. 56)

Table 4.2 Project Features linked to D&T Teacher Minimum Competences

Teacher Competencies	Corresponding Project Feature
Core Design :	
Understand and use a range of strategies and approaches to identify and clarify design problems.	<p>Mechanism understanding and analysis. To calibrate the regulator, understand material properties utilised for structure and movement.</p> <p>Use of modern laser cutting as a constraint for CAD/CAM based design and the unique solutions it creates.</p>
Compile a design brief and specification. Demonstrate that a product design specification may have a number of requirements and use these to evaluate design ideas throughout designing and making.	<p>Differentiation between functional mechanism constraints and the freedom of aesthetical design elements and how they can be altered in the product.</p> <p>Generation of specific technical requirements that can be tested.</p>
<p>Use techniques, processes and procedures appropriate for each of the specialist fields to manufacture products and systems.</p> <p>When planning and conducting design and technological activities, give due regard to Health and Safety of their pupils, themselves and other adults. Show awareness of current, relevant Health and Safety responsibilities, legislation and liability.</p>	<p>Use of integrated CAD/CAM technology with 2D design and laser cutting.</p> <p>Risk assessment and understanding of risk with laser cutting equipment. Beam and Non-beam hazards, COSHH requirements. Correct and safe working/maintenance practices with laser cutters.</p>
Demonstrate an understanding of the contribution Design and Technology makes to pupils numeracy, literacy and language development including technical language when talking and writing about designing and making.	<p>Use of correct technical language with mechanical components.</p> <p>Incorporation of mathematical calculation to the technical design.</p>
Nurture a creative teaching and learning environment where pupils feel confident and safe to experiment, explore and take risks.	<p>Project encourages and experiential learning environment where pupils can quickly manufacture and investigate designs through the use of laser cutting.</p>

Teacher Competencies	Corresponding Project Feature
<b>Electronics and Communications Technologies (ECT):</b>	
<p>Tier 1: Design simple mechanical solutions incorporating cams, levers, gears and pulleys.</p> <p>Tier 1: Prototype simple mechanical solutions incorporating cams, levers, gears and pulleys using both made and bought elements.</p> <p>Tier 1: Describe: (1) a range of simple mechanical devices and drive systems; (2) the forms of mechanical movement and the use of mechanisms to translate between them.</p> <p>Tier 2: Understand the principles of use of an appropriate range of mechanisms, including considerations of power transfer (eg. simple and compound gear trains, pulley systems, cams).</p> <p>Tier 1: Analyse the design of mechanical, electrical and electronic products in terms of who they have been designed for, the design features that suit them to these users and their technical operation at a systems level.</p> <p>Tier 2: Make use of their technical understandings of components and systems to analyse and describe the operation of mechanical, electrical and electronic products.</p> <p>Tier 2: Apply appropriate technical principles and concepts in the analysis of the function of a range of mechanical, electrical and electronic products.</p>	<p>The design incorporates gears, a range of moments and forces can be calculated. Understandings of friction in the working of bearings and the pendulum.</p> <p>The system translates Gravitational Potential Energy through a rotating barrel (moment) to create a rotation of a hand and the motion of a pendulum. This is a complex system to model, calculate and describe.</p> <p>Analysis and investigation of the mechanism is required to calibrate the timekeeping functionality. This requires a functional understanding of the mechanism to be able to relate theory to practice.</p>
<b>Resistant Materials Technology:</b>	
<p>Tier 1: Make use of modelling techniques to model artefacts made in wood, metal and plastics (eg. using basic modelling materials such as straws, foam, card, polymorph).</p> <p>Tier 2: Use more complex models to test a technological principle (eg. Using commercial kits or components to test a mechanical movement using cams or linkages).</p> <p>Tier 1: Make use of CAM prototyping techniques to synthesise and develop design ideas (eg. rapid prototyping, stereo lithography, laminate assemblies).</p> <p>Tier 2: Use CAD/CAM to aid manufacturing to achieve appropriate and repeatable quality, reliable function (eg. making jigs for standardised components, mould making for casting or vacuum forming), and ensuring fit (eg. interference fit),</p> <p>Tier 1: Generate working drawings using CAD (eg. cutting lists, dimensioning and appropriate BS conventions).</p> <p>Tier 2: Generate detailed working drawings using CAD, including assembly, parts and sectional views.</p> <p>Tier 1: Accurately draw construction details using formal drawing techniques, to show how wood, metal and plastics can be used to make artefacts (eg. orthographic drawing).</p>	<p>Parts of the functional elements can be modelled prior to final construction to be able to understand the effect of gear ratios with a practical example.</p> <p>The resource requires the use of CAD/CAM technologies and for students to modify the designs provided to develop their own customised versions.</p> <p>A variety of outputs can be produced from the CAD data including working drawings, and assembly plans.</p> <p>Designs can be produced in 3D modelling software to enhance CAD learning and provide further development of outputs.</p>

Teacher Competencies	Corresponding Project Feature
<b>Resistant Materials Technology:</b>	
Tier 1: Access design data, using IT relating to for example the properties of materials, standard sizes, fixings, adhesives and components.	Research into appropriate materials by students, must be cross referenced with materials suitable for laser cutting.
Tier 1: Understand how wood, metal and plastics resist forces, such as compression, tension, torque and bending.	The complex mechanism can be used to teach physics concepts and incorporates forces, such as compression, tension, torque and bending.

Note: Tier 1 = Key Stage 3, Tier 2 = Key Stage 4 and post-16.

Adapted from: (Design and Technology Association, 2003, 2010; Loughborough University, 2011)

#### **4.2.2. Design**

In this exploratory study, qualitative methods provided the best solution to generating an understanding of teacher behaviour with the created resources. Fieldwork, constructed from multiple observations, was used in this study. The triangulation of multiple sources was necessary to provide a more complete perspective that would not be achievable using a single source (Patton, 2002). A comparison of data generation methods is provided in Table 4.3 with the advantages and disadvantages of each method.

This study aimed to determine the factors that affect the adoption of new technology curriculum resources within secondary schools. To achieve this observation methods were selected as they are suitable for investigating phenomena under natural conditions (Wilson, 2009).

Table 4.3 Advantages and Disadvantages of Data Generation Methods

Method	Advantages	Disadvantages
Unstructured Interview	Increases the relevance of questions. Questions emerge from observations. Can be matched to individuals and circumstances.	Different information collected from different people with different questions. Less systematic. Necessary/relevant questions may not arise. Difficult to organise and analyse data.
Structured Interview	Simple data analysis. Time efficient. Responses from different participants can be directly compared.	Participants must fit their responses into pre-determined categories. Pre-determined questions can distort or limit responses. Can be perceived as impersonal, irrelevant and mechanistic.
Focus group	Produce insights that may not occur in a standard interview. Efficient use of time. Empowering participants to speak. Greater coverage of issues than would be possible in a survey.	Unnatural setting. Does not produce as much data as one-to-one interviews.
Observations	Gathers 'live' data from naturally occurring situations. Potential to provide more valid or authentic data than inferential methods. Participants may prefer this over time consuming interviews or questionnaires. Collects non-verbal data.	Selective attention of the observer. Participants react to the observer's presence. Selective data entry. Selective memory in writing up observations. Inference of observed behaviours.

Source: (Cohen et al., 2007; Patton, 2002)

### 4.2.3. Sampling

The sample was drawn from 18 D&T PGCE trainees registered on the PGCE at Loughborough University. The sample was purposive; in that participants were chosen on the bases they would be able to provide useful insight and that they have certain criteria that will help test theory (Mason, 2002).

Purposive sampling is often used in qualitative research to create information rich cases which will reveal the questions under study (Cohen et al., 2007; Patton, 2002).

Of the 18 trainees, six initially agreed to participate. These six participants were linked to four teacher training schools as part of their training. The six participants were selected to deliver the project as part of their teaching practice and were allowed to utilise the work for the study as part of their PGCE assessment to minimise any additional workload. During the study two participants withdrew leaving a final sample of four trainee participants at three schools.

#### **4.2.4. Procedure**

##### Phase 1

Participants were invited to a workshop at Loughborough University. Participants were provided with written and verbal instructions during the workshop. The aim of the workshop was for the participants to test the resources and experience the activities required in the project before taking the resources to their school. Trainees built their own mechanisms following the assembly instructions using the parts and tools supplied. This was used to troubleshoot the assembly process and a discussion allowed them to express any concerns they had with the design, and how they would implement the resource.

The workshop was delivered by the researcher and feedback was obtained from participants. Feedback was obtained from the workshop participants in relation to the project and their initial observations. The feedback was recorded by the researcher and is presented within the results. The assembly guide was modified according to the workshop feedback for use in the following phases.

##### Phase 2

Following the workshop, the participants delivered the project to the remaining sample of 13 D&T PGCE trainees. The aim of this session was to allow the participants to gain some experience in teaching with the resources before going into school. In addition, feedback was obtained on the resources from the whole sample. The recordings made by the researcher are presented in the results.

##### Phase 3

The participants were then asked to deliver the project in school during their teaching practice. Initially participants and their mentors in school (participant/mentor dyads) met with the researcher to describe their intentions. In addition, discussions took place regarding the implementation of the projects in school. It was at this point that the two participants withdrew from the study. The reasons given are presented in the results.

During the following six weeks, whilst the participants were on placement in schools, communication was maintained with the participants by the



researcher. This was to obtain feedback on any problems and allowed the participants to report difficulties.

At the conclusion of teaching practice, the researcher observed the final teaching session to see the completed projects.

#### Phase 4

Following the completion of the teaching activities for the project, a focus group was undertaken with the remaining four participants once they had returned from their teaching practice. The aim to of the session was to gather final feedback on the project from the participants. Participant responses were recorded by the researcher.

#### **4.2.5. Analysis**

The data from this initial study was analysed using deductive or theoretical thematic analysis (Braun & Clarke, 2006). This 'top down' approach analysed the data using the theoretical knowledge domains identified in Chapter 2 and was chosen to provide detailed analysis in relation to the specific aims of the study.

The data generated were written up promptly and formed into field notes (Cohen et al., 2007). Field notes from all phases were coded under the following categories; Content and Subject Knowledge, Technological Knowledge, Pedagogical Knowledge, Pedagogical Content Knowledge, Curriculum Knowledge, School Knowledge and Personal Subject Construct. In addition to the categories identified in the literature review, results were coded under Pupil achievement.

#### **4.3. Results**

This section reports the combined findings from all phases of the research. Demographic details of participants are shown in Table 4.4. All participants in this study went onto pass their D&T PGCE training program and gained Qualified Teacher Status. The schools utilised in the study followed the National Curriculum.

Table 4.4 Participant information

Participant	School	Age	Prior Degree
A	1	21	(2:1) BA Creative arts & design
B	1	22	(2:1) BA Creative arts & design
C	2	26	(2:2) BA Creative arts & design
D	3	24	(2:2) BA Creative arts & design
E	4	22	(2:2) BA Creative arts & design
F	4	22	(2:1) BEng Engineering & technology

### Procedural Content, Subject Knowledge and Technological Knowledge

During each phase of the study participants demonstrated a lack of procedural knowledge in relation to using the laser cutter and assembly skills. Only three participants had previous experience of using a laser cutter before the project. During Phase 3 the participant/mentor dyad in School 2 reported that they were unsure of what to do with the laser cutter. However, the participant at School 2 investigated appropriate teaching methods and developed their skills in this area prior to teaching. School 3 had recently purchased a new laser cutter and the mentor reported no previous school projects or experience with the equipment. In both of these examples the participants were aware of their lack of training. During the final focus group (Phase 4) it was established that the participants had received some training on using the laser cutter in school. The discussion revealed that the teachers thought their in-school training with laser cutters was insufficient and they would like to have further training.

The 13 trainees in Phase 2 demonstrated individual differences in following assembly instructions. The assembly process and associated instructions had been successfully piloted during Phase 1. Suggested improvements to the instructions, from feedback in Phase 1, had been made before Phase 2. This demonstrates that the instructions could be followed to successfully assemble the mechanism, and that difficulties lie within teachers' incompetence not incorrect instructions. One group in Phase 2, containing 4 trainees, demonstrated an inability to follow the instructions to assemble the pairs of gears.

### Conceptual Content, Subject Knowledge and Technological Knowledge

During each phase the participants demonstrated varying levels of conceptual knowledge related to the project. This was in relation to the gear

and mechanism theory, mathematics, science and manufacturing process knowledge.

During Phase 2, participant F demonstrated appropriate conceptual knowledge as the sample of trainees working with this participant completed their task in the shortest time and with the fewest issues. Participant F and their sample group were able to conduct the investigative learning activities the mechanism was intended to teach. The other participants in Phase 2 had difficulties in completing the tasks and were unable to explain how the mechanism worked.

During Phase 3 participants reported difficulties with their understanding of the technology and engineering aspects of the project. The participant/mentor dyad at school 3 reported that the project was more complex than existing projects at the school and that existing projects were more creative based. The participant/mentor dyad at school 2 reported their experience was with textiles and not with the technology in this project.

#### Pedagogical and Pedagogical Content Knowledge

There was evidence of participants developing Pedagogical Content Knowledge and incorporating technology into their classroom. Participants drew on their subject and pedagogical knowledge and created lessons that covered some of the possible technology areas for which the project was suitable.

The participant/mentors dyads in schools 1, 2 and 3 developed different plans to teach the project. In school 1 the project was taught over three lessons in an after school club for gifted and talented year nine pupils. These sessions covered an introduction to gears, product design of products with gears and the assembly of the mechanism. Participants in school 1 created their own additional resources to enable teaching of the project, these tasks required pupils to calculate gear ratios and compound gear trains.

In school 2 the project was taught in 12 normal curriculum time lessons to year eight pupils. The plan to integrate the mechanism resources into a class project covered an introduction to the timer and mechanisms, writing a brief and specification for their timer, developing design ideas, developing further understanding of gears, importance of following instructions, problem solving and working out any problems with the timer, developing design ideas,

planning making, making final design idea, scales of production, evaluation and group presentations.

In school 3 the resources were used in a ten lesson curriculum time project for year nine pupils. The lessons covered an introduction to motions, mechanisms and gear ratios; how to manufacture some of the mechanisms to create the different outputs; continue to reproduce their mechanisms, and beginning to familiarise themselves with CAD; design a range of slotting techniques to demonstrate understanding of how the clock will go together; designing a mood board to inspire their clock casing design; developing their design ideas in preparation for cutting out; construction of the gears and escapement mechanisms; finalising the design of their clock casing; final assembly of their clocks and the evaluation of the project as a whole.

A trainee in the Phase 2 sample provided evidence of establishing Pedagogical Content Knowledge as they were able to draw on their prior experience and knowledge associated to the project and propose a suitable way to deliver the content.

The workshops in Phase 1 and 2, and communications before teaching began in Phase 3 were designed to enable participants to develop their methods for delivery of the project. The concerns of the participants were focused on why the project could not be taught. An example of this is from participant A, whereby in their communication they are fixated on the project not being suitable due to the assembly process:

*“It’s the use of the paperclips that is the main problem; they are sharp and bend when you put them into the design”*

Participant D understood that the project would increase the level of technical content taught in classes and that it built upon previous basic mechanical projects. In planning the project participant D related the project to previous learning:

*“They [pupils] are currently working on Automata which I think will lead nicely into the mechanical clock as they will have some basic knowledge regarding motions, inputs and outputs.”*

### Curriculum and School Knowledge

The reason for the withdrawal of the participants at School 4 was provided by mentor at that school:

*"[...] the project was not compatible with either our current schemes of work or controlled assessment tasks set by the exam boards."*

The withdrawal was received by the researcher after evaluating with the participant/mentor dyad how to include the project into the school's curriculum. The reason given for the withdrawal of Participants E and F at School 4 is evidence towards the impact of school knowledge on implementing new projects, and how the existing school knowledge prevents new staff from developing projects.

The participant/mentor dyads demonstrated their preference for delivering long projects as extended design and make tasks for pupils, following the 'design process'. In school 1 the participant/mentor dyads reported that their existing laser cutting projects are taught over seven weeks. With the additional complexity of this project 15 weeks would be required to teach it. The project was considered unsuitable as it did not contain enough design work and the mathematics level was too high.

The school knowledge impact on adopting new projects was evident in Phase 3. Participant D intended on using new materials with the machine for pupils to investigate, however, the head of department at school 2 intervened to stop an aspect of the project without providing a sound reason or solution to the problem. This was reported by the participant/mentor dyad at school 2:

*"[the participant] has been trying to work on this idea in various materials as the head of department is unhappy with us using MDF as she believes that it blocks the filters. If you could offer some advice on this area."*

This problem provides evidence that the combined school knowledge does not understand the classroom equipment.

### Personal Subject Construct

During each phase of the study participants demonstrated their beliefs that the project was unsuitable for pupils. The participant/mentor dyads at schools 1 and 3 were concerned with the difficulty of the project.

The participant/mentor dyad in school 1 reported that the content was only suitable for high achieving pupils. This is evident in their choice of delivery method:

*“We have talked through several delivery methods and settled for a G&T [gifted and talented] or near G&T focussed afterschool / lunchtime skills club, so that the key problems can be ironed out before involving a wider field of abilities.”*

Participant A also provided evidence of their personal opinion towards the project. They believed that the level of the content was not suitable for all year 9 pupils, but also that it would not be interesting to the pupils.

Participant A described that the project required changing to be “*something interesting*” and “*not scary*” in order to be suitable for pupils.

The final lesson observations in Phase 3 revealed that pupils at school 2 were not given access to the laser cutter and did not get to see their parts being manufactured. In this situation the laser cutter was kept in a separate workshop making it difficult for students to get access to the machine. The participant/mentor dyad reported uncertainty in using the technology, as they were specialists in textiles and did not normally use the machine.

### Pupil Achievement

The final lesson observation within school 1 showed that the additional resources developed by the participant had been successful in teaching pupils about complex gear ratios. Pupils were taught how to use the laser cutter and what materials were suitable to use with the laser, but no description of why certain materials are not suitable. Preparation of CAD files was the main emphasis of the laser cutting lesson.

Pupil’s end of project presentation of their work in school 2 was used to provide evidence of learning of technical content related to the gear mechanisms. It was reported by the participant/mentor dyad in School 2 that the pupils had really excelled and been interested in the mechanism design,

and that it had engaged those normally considered by the mentor to be less able. This was achieved through effective group work. There was no evidence that pupils' knowledge of laser cutting had been improved, or that any of the lessons had focused on this aspect.

Participant D at school 3 reported difficulties in getting pupils to engage with technology throughout the project. There was no evidence in the final lesson observation, in which it was planned for pupils to conduct an evaluation of the project as a whole, of learning about the mechanism. Pupils had acquired some basic CAD skills and achieved a level of knowledge and skill that enabled them to operate the laser cutter. Pupils had been able to customise their parts by engraving designs developed from their mood boards. The reason for this level of interest from pupils was given by the participant as:

*"[pupils have] already picked their GCSE options"*

#### **4.4. Discussion**

##### **4.4.1. Suitability of the resources created**

The key finding of this study was that in all phases participants reported that the project was too difficult. In this section, the difficulty of the project for pupils and teachers is discussed. This study used three sources of information in the development of the resources. The National Curriculum (Qualifications and Curriculum Authority, 2007) contained the targets for pupil attainment, the D&T Association minimum competences (Design and Technology Association, 2010) outlined what a teacher should know and the review of best practice allowed comparison to other work. This section of the discussion argues that the project was suitable for pupils and teachers.

The features of the project and learning opportunities were in alignment with the D&T KS3 National Curriculum Range and Contents shown in Table 4.1. However, it may have been possible for the project to meet the range and content for the National Curriculum yet not be suitable for pupils at a specific school, as the pupils may not have been prepared or taught the foundation work required. The purposive sample was selected in an attempt to address this issue. Teachers are given autonomy to make their own professional decision about the specifics of what to teach as long as it meets the National

Curriculum (Zanker, 2008). This demonstrates how the autonomy given to teachers allows topics to be avoided during KS3. It was reported by participant D that the project did fit into prior learning of the pupils in that school. This demonstrates that the topics in the project do extend pupils existing learning within the national curriculum.

It is difficult to define exactly what a D&T teacher should know, in terms of subject and technology knowledge. The teaching in D&T requires the teacher to have both conceptual knowledge about technology and procedural knowledge of using technology for manufacturing (McCormick, 1997; Moreland & Cowie, 2007; Norström, 2014; Parkinson & Gill, 2009; Stein et al., 2002). The analysis of this project encountered McCormick's (2004) complex relationship between conceptual and procedural technological knowledge.

Teachers are not required to have any knowledge of laser cutting or required to teach it. Teachers decide themselves which manufacturing processes and skills they will teach (Qualifications and Curriculum Authority, 2007; Zanker, 2008). This is still true in the latest version of the national curriculum (Department for Education, 2013a). Teachers are however required to teach CAM. Davies and Hardy (2015) describe the choices available to teachers; laser cutters are one of the options for CAM alongside knife cutters, milling machines, computer controlled sewing machines, additive manufacturing and dye-sublimation printing. The schools selected in the purposive sample all had laser cutting equipment.

Teachers do not have to teach clocks or timing mechanisms but a 'clock project' using quartz mechanisms are commonly found in school (Martin, 2013). This project integrated the teaching of mechanical systems into the traditional 'clock project' and it was expected that teachers would be able to understand this through identification of the relevant competences. The competences the sample were trained to (Loughborough University, 2011), adapted from the D&T Association minimum competences for KS3 teaching (Design and Technology Association, 2003, 2010), state that teachers should be able to:



*“prototype simple mechanical solutions incorporating cams, levers, gears and pulleys using both made and bought elements”.*

*(Loughborough University, 2011, p. 100)*

Therefore, even if a teacher chooses another way to deliver this content in their KS3 curriculum, it would be expected that teachers should understand or at least be familiar with other examples of this technology conceptually and procedurally. However, the results presented evidence of poor procedural assembly skills with this competency.

Complexity was found in the individual expertise of D&T teachers. The D&T trainees ITT program assessed competence in all of the core design competences, two specialist areas to KS3 level and one specialist area to KS4 level and beyond. This may have resulted in teachers being specialist in, and therefore restricted to, only one area of the D&T curriculum; this was reported by the participant/mentor dyads at schools 2 and 3. Commonly school's solution to having only specialist teachers is the use of a 'carousel' system where pupils rotate between classes that teach the specialist areas (Wakefield, 2013), this has been associated with academic regression of KS3 pupils (Gronney, 2013; Ofsted, 2011b). In reported best practice of D&T teaching 'carousel' systems are not used; teachers have knowledge and skills in all areas (Ofsted, 2012). The National Curriculum does not state that the subject should be taught in separated areas and it is suggested that areas should be combined:

*“Product areas may be combined where appropriate”*

*(Qualifications and Curriculum Authority, 2007, p. 55)*

The specialisation of teachers can be used to explain the delivery of the project whereby their specialisation restricted the potential diversity in the subject. Varying levels of conceptual and procedural knowledge were observed from the participants in relation to the different aspects of the project and participants reported a lack of understanding in technical concepts.

Trainees in Phase 2 appears to have difficulties in following the assembly instructions. These instructions were developed following appropriate methods to produce a clear set of step-by-step guides with appropriate exploded diagrams (Agrawala et al., 2003). The first version of the guide was

successfully piloted during Phase 1, and some small changes to the labelling and identification of parts were made based on Phase 1 feedback. Pupils in schools also demonstrated their ability to follow the instructions as pupils successfully manufactured their own mechanism. Therefore, the assembly guide can be considered to be suitable.

#### **4.4.2. Factors affecting the adoption of the resources**

The participants' subject knowledge appeared to influence their ability to adopt the resources. Participants did not show evidence of a complete ability in the competences they were being asked to deliver. There were large variations in understanding of the technical concepts in the sample in Phase 2. Participants directly reported having issues with the content of the project during Phase 3. Although the project fits within the National Curriculum and the D&T Association teaching competence, as discussed above, the level of the work exceeded the schools existing schemes of work. This is a key finding and is supported by the participants' background knowledge and the discussions in Chapters 2 and 3. The prior chapters have identified the mismatch in teachers own technical knowledge and the technical knowledge required to teach D&T as a potential cause for a lack of technology teaching. The 4 participants who completed the project had their previous degree in creative arts and design.

The only participant with a previous degree in engineering and technology showed the best performance in Phase 2 when working with the other trainees. This participant had the procedural knowledge of the CAD, laser cutter and assembly skills and conducted the analytical activities with their Phase 2 group to teach the conceptual technical content. There is however, no evidence for this teacher beyond Phase 2 as they withdrew from the research. The reasons for the withdrawal are discussed below.

Teachers knowledge may also impact their beliefs on the content. The participants at school 1 did not appear to have a productive disposition towards seeing the technology as useful and worthwhile (Schunn & Silk, 2011). The participants did not consider the project interesting and thought it might put off pupils. This may introduce problems in the project delivery as the motivation of teachers is important to pupil learning (Hill, 2007).

The concerns of the sample and participants in Phase 1 and 2 for the project were concerns of self and not concerns of the pupils. This is to be expected from trainee teachers (Fuller & Bown, 1975; Veenman, 1984).

Factors affecting the adoption of the resources in this study were not just influenced by the individual participants. The influence of School Knowledge, the schools historical approach and the combined behaviour of staff and the head of department can also be seen (Barlex & Rutland, 2008; Ellis, 2007b; Shulman & Shulman, 2004).

The reasons for the withdrawal participants from school 4 present an interesting factor affecting the adoption of new projects. The participant/mentor dyad reported that the project was incompatible with the schools current schemes of work and the exam board assessment. The previous section of this discussion has provided evidence that justifies the suitability of the project for schools. The findings from school 4 support other findings in the literature by Atkinson (2000b), Banks *et al.*(2004) and Barlex and Rutland (2008) as identified in Chapter 2. In these cases the teachers were resistant to improve and update their existing schemes of work when new ideas were brought into the school and the teachers were provided with artificial positive feedback of the performance of their teachers' current practices, from exam scores.

The freedom given to schools to implement their own specific curriculum, within the guidelines of the National Curriculum creates a School Knowledge of what level pupils should be taught to on individual topics and what the focus of work should be. The evidence of this School Knowledge is found in the different delivery methods used in the schools. The participant/mentor dyad in School 1 chose to deliver the project to only gifted and talented students; compared to School 2, where the project was delivered to an entire year 8 class. The level of pupil achievement was different in both of these situations. The gifted and talented pupils in School 1 had done mathematics-based tasks and were successful in building and analysing the mechanism. Pupils in School 2 demonstrated comprehension and analysis of the gear mechanisms, but not the pendulum or laser cutting technology. In these situations the pupils demonstrated higher levels of cognitive ability in the

areas of gears, but only basic knowledge of the timer as a whole or with the laser cutting project.

The emphasis on developing a deep understanding of the technology is to achieve the higher levels of cognitive ability according to the taxonomy of educational objectives (Bloom et al., 1956). This will enable pupils to go beyond specific knowledge and basic skills and will enable high-order capabilities such as critical thinking, creativity and problem solving (Barak & Hacker, 2011; Wu, Custer, & Dyrenfurth, 1996).

There were conflicting beliefs between the schools on the use of laser cutting technology. The participant/mentor dyads in School 1 and 3 were able to use their laser cutters and allowed pupils access to the equipment. In School 2 the participant/mentor dyad was unsure of the suitability of materials for cutting and they did not allow the pupils access to the technology. D&T is about learning skills as well as knowledge and not having access to the technology will be detrimental to pupils as learning can be gained from experiences with the technology (Kolb, 1984).

The use of the 'design process' was a factor affecting the adoption of this project as the participants used this process to develop their schemes of work. The project was delivered as an extended design and make assignment in Schools 2 and 3. The participants at School 1 delivered the project as a focused practical task in an after school club, they reported it would have been taught as an extended design and make assignment if it had been in curriculum time. Using the resources in the 'design process' to develop a product should provide the benefit of context and realism to pupils (de Vries, 2007; Dreyfus & Dreyfus, 1980; McCormick, 2004). However, it typically becomes a linear set of tasks for pupils to complete (Mawson, 2003), resulting in the completion of tasks that do not benefit the design or provide learning:

*“many still spend too much time on superfluous decoration of their design folders rather than on real design development.”* (Ofsted, 2002, p. 2)

*“[...] pupils inventing ‘initial ideas’ after their design is finished!”*  
(Banks, 2008, p. 184)

There is evidence that these types of tasks were introduced as part of the schemes of work in Schools 3. In participant/mentor dyad at School 3 included multiple lessons on developing 'design ideas' using mood boards to customise the graphics that were engraved on the mechanisms. Following the 'design process' strictly can introduce unnecessary tasks to the project and turn small learning opportunities into major length projects.

An interesting phenomenon occurred in school 3, whereby the pupils were not interested in the project due to their GCSE selections. As these pupils had selected not to study D&T beyond compulsory KS3 level they were reported to be unmotivated by the participant. This finding fits within the decline in pupils studying technology subjects beyond KS3, as identified in Chapter 1.

#### **4.4.3. Limitations**

A non-random sample was utilised in this study. The sample was selected purposively to provide useful insight into the specific problems being examined. The results therefore reflect the observations of a small group of individuals and may not be representative of the population of D&T teachers. However, the results are insightful and identify areas for further study.

References in the literature to similar results have been made to compare the sample results to other studies. Trainee teachers were used as they were accessible to the researcher, however future studies must sample from the population of experienced teachers to address any potential bias introduced by the participants level of experience.

Observation methods were used to generate the data analysed in this study. The quality of the data generated by observations are affected by the selective attention of the observer, participants reactions to the observer's presence, selective data entry, selective memory in writing up observations and the inference of observed behaviours (Cohen et al., 2007; Patton, 2002). Data triangulation (Guion, Diehl, & McDonald, 2011) was used to provide validity to the data. Limitations to the methods of data generation will be addressed in later chapters.

#### **4.5. Summary and conclusions**

The study described in this chapter sought to explore teachers' usage of new technology resources for D&T. Specifically the study aimed to develop a novel set of resources for teaching technology in KS3 D&T. One Key finding of the study was the level of difficulty that the resources presented to the participants. As teachers are given autonomy to teach the National Curriculum with their own content and methods, it is not possible to define if a teacher or pupil should be able to do any particular project within D&T. However, the resources designed for this study did fit within the National Curriculum and the D&T Association Minimum Competences for Trainees to Teacher D&T in Secondary Schools and have been shown to be appropriate for schools. The purposive sample chosen also ensured that the schools followed the national curriculum and had access to the technology that was used in the study. The participants delivering the project should have been capable of delivering the resources, from the perspective of the National Curriculum and the competencies they were trained to.

Factors that affected the adoption of the teaching resources created for the study were identified in the analysis. The first factor identified was the misaligned technical subject knowledge of participants. The teachers' background knowledge, as identified in Chapter 3, appeared to influence their ability to deliver new technology content to pupils. The flexibility in the interpretation and assessment of D&T teacher to the minimum competences allows for highly specialist teachers with gaps in their technical knowledge. This study was conducted under the 2007 version of the National Curriculum and it would be appropriate for further work to discuss the effect that the identified subject knowledge issues would have with the latest version of the National Curriculum.

The results have also shown the impact that the collective school knowledge and curriculum have on the adoption of new resources. The separation of the D&T curriculum into multiple subject areas prevents multi-disciplinary projects from being taught. These artificial subject area constraints are removed in the latest KS3 National Curriculum (Department for Education, 2013a) and the changes in the proposed draft GCSE specification (Department for Education, 2015a). This should reduce the impact of these

problems if teachers adopt new practices and change their existing curriculum and school knowledge.

Further work emergent from this study would be to analyse methods for improvement of teachers' technological and subject knowledge. Firstly, a detailed study of the specific case of the knowledge required to use laser manufacturing technology, and secondly, a study to look at the broader spectrum of teacher professional development in technology. Within these studies is the necessity to analyse teachers beyond their ITT programmes. The further analysis of teachers should be used to validate the knowledge gaps concluded in this chapter and Chapter 3. A more thorough study of pupils' ability and motivation in technology education is required to conclude the effects of teachers' performance.

## **5. Testing a technology CPD course**

### **5.1. Introduction**

This chapter presents the findings from an evaluation of a newly developed CPD course for D&T teachers. The course was designed with the aim of creating and analysing interventions to improve technology education. The vast majority of CPD options for teachers are provided by awarding bodies to train the specific requirements for examinations (Kimbell, 2012). Although teachers in the UK engage in CPD, an individual teacher conducts relatively little CPD compared to teachers in other countries (Kimbell, 2012). In previous chapters it has been demonstrated that teachers encounter problems with using laser cutters in teaching and have low subject knowledge in this area. To address these matters a new CPD course was developed with a focus on developing teachers' subject knowledge in the use of school laser cutters.

#### **5.1.1. Aims of the study**

The specific aims of this study were to:

- Improve teacher technological subject knowledge in the use of laser cutters in school via a subject knowledge improvement one day course.
- Measure changes in teachers' confidence in teaching the content associated with laser cutter attributed to attendance on a CPD course.
- Study teachers' reactions to a technology subject knowledge CPD course.

### **5.2. Method**

#### **5.2.1. CPD Course**

The one day Teaching with Lasers CPD course was developed for this study. The development of the course was guided by the findings from the previous chapter, the teacher knowledge domains identified in the literature and by expert opinion, see Figure 5.1. Resources for the Teaching with Lasers course were adapted, to suit teachers, from an undergraduate mechanical engineering module on the same technical topic and industrial laser safety training programmes run from the institution. These adaptations were made



to reduce the content of the lectures to the equipment available in schools; to reduce the total amount of time spend covering topics; to remove formulae unnecessary to teachers and pupils and to structure the content to fit within a one-day course.

<p><b>Existing Knowledge</b></p> <ul style="list-style-type: none"> <li>• laser cutters are currently used as a workshop machine, not as a tool for learning technology,</li> <li>• the technology is not well understood,</li> <li>• varying levels of experience,</li> <li>• teachers do not currently teach about the technology.</li> </ul>	<p><b>Developing Technological Pedagogical Knowledge</b></p> <ul style="list-style-type: none"> <li>• how it is safe for pupils to use the machinery,</li> <li>• how the machinery can be beneficial to teaching,</li> <li>• what specific functionality is beneficial to pupil learning.</li> </ul> <p><b>Developing Pedagogical Content Knowledge</b></p> <ul style="list-style-type: none"> <li>• classroom relevant information about the technology</li> </ul> <p><b>Developing Technological Content Knowledge</b></p> <ul style="list-style-type: none"> <li>• deep understanding of materials and capabilities of the machinery,</li> <li>• industrial relevance and knowledge.</li> </ul>
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Figure 5.1 Teacher Knowledge framework used to develop course

The focus of this training course was to provide D&T teachers and trainee teachers with the appropriate subject knowledge to be able to teach with laser cutting technology. The course included:

- Lectures on laser use in industry that would allow participants to relate classroom work to industrial processes and common products.
- An introduction to the underlying technology; linking equipment functions with results in various materials.
- Information on laser safety and the particular hazards that are commonly overlooked when buying and operating a laser cutter.

The timetable of activities is shown in Table 5.1.

The technology pupils have access to in school are used by many engineering companies for the production of a wide variety of products, including, but not limited to, sheet material fabrication, textile cutting for fashion, engraving and product labelling, electronics and semiconductor manufacture. For this reason, demonstrations of industrial and school laser materials processing equipment were included within the course.

It has been shown that high school pupils have little or incorrect perceptions of engineering education (Bowen et al. 2007). Therefore, the course included

a short presentation about the requirements to studying engineering in higher education. This was included to help teachers to discuss with their pupils why STEM subjects are relevant in schools and how useful and applicable the technical knowledge is beyond their secondary school education. The course was to develop teacher's technical subject knowledge and enable them to deliver improved teaching with this technology.

Samples of example advanced laser cutting projects were given to all attendees. Lectures contained interactive elements to allow reflection on knowledge gained. The course was not intended to train people to use specific laser processing equipment but to provide the conceptual subject knowledge base from which to teach with, and this was made aware to participants when advertising the course.

Table 5.1 Timetable of CPD course activities

Time	Activity
09:30 – 10:00	Arrival and registration
10:00 – 11:00	Welcome, Review of lasers in schools exercise, Laser introduction and material interaction lecture.
11:00 – 11:15	Break with refreshments
11:15 – 12:30	Laser Drilling and Cutting lecture
12:30 – 13:15	Lunch
13:15 – 14:15	Lab based activities: Industrial equipment and processes, Project demonstrations, Safety
14:15 – 15:00	Laser Safety Lecture
15:00 – 15:15	Break with refreshments
15:15 – 16:00	Undergraduate engineering, Developing new teaching practices exercise and discussion
16:00	Finish

### 5.2.2. Sampling

The course ran in February 2014 at Loughborough University. A maximum of 22 places were made available for the course. The first 9 places were allocated to the Loughborough University D&T PGCE trainee teachers. The remaining 11 places were advertised through the Universities' partnership schools, on the Laser Made Mechanical Timer project resource website and in an advert in the local newspaper. The places were allocated on a first come first served basis providing a convenience sample (Cohen et al., 2007). Participants were notified of the research activities taking place and were

asked to evaluate the course and all gave informed consent in agreement to participate. There was no cost to the participants to attend the course.

### **5.2.3. Procedure**

#### Pilot

The course content and initial versions of the evaluation questionnaires were piloted on a trial run of the course with a group of trainee D&T teachers in 2013. As a result of the pilot study, the course content was reduced. The final questionnaires used following the pilot can be found in Appendix B - Questionnaires used in Chapter 5.

#### Phase 1

All participants were asked to complete the online pre-course questionnaire before their attendance on the course. The links to the questionnaire were emailed to all participants once their registration was confirmed. This questionnaire was made up of 3 sections. Section 1 requested the background training of the participants and their experience with laser cutters. Section 2 requested participants to rate their agreement to 14 statements about their use of laser cutters in school and their confidence in teaching pupils laser cutting in school on a 5 point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree). This section would be repeated in the post-course questionnaire during Phase 3 of the study to calculate any effect that the course had to these items. Section 3 requested participants to rate their agreement to 8 statements about STEM in D&T using the same 5 point Likert scale as section 2. The online questionnaire allowed participants to leave feedback on any of the items.

#### Phase 2

The Teaching with Lasers CPD course was run at Loughborough University during the half term holidays in February 2014. The content of the course, as previously discussed, was delivered to the participants by a university Professor in Laser Materials Processing. During the course lectures, 19 questions were given to assess participants' technological knowledge and learning during the course. Participants were requested to rate their agreement to the questions on a 3 point Likert scale (1 = Disagree, 2 =

Neither Agree nor Disagree, 3 = Agree). An Electronic voting system was used to capture participant responses during the lectures.

### Phase 3

Following the course, participants were emailed a link to the post-course questionnaires. Sixteen participants completed the questionnaire at both time points. Certificates of attendance were given to participants on completion of the questionnaire and were used to incentivise participants. The post-course questionnaire was made up of 5 sections. Section 1 requested participants to rate how relevant they thought sections of the course were for themselves and for their pupils using a 5 point Likert scale (1 = Very Irrelevant, 2 = Irrelevant, 3 = Neutral, 4 = Relevant, 5 = Very Relevant). Section 2 of the post course questionnaire was identical to section 2 of the pre-course questionnaire. Section 3 requested participants to rate their agreement to 10 statements about their teaching of other technology topics in school on a 5 point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree). Section 4 requested participants to state if they were interested in attending CPD courses on 7 other technology topics. Section 5 requested participants to give any feedback they had on the course. The online questionnaire allowed participants to leave feedback on any of the items.

### Missing Data

A summary of the number of responses to the questionnaires, and the missing responses are shown in Table 5.2. The level of missingness for individual variables varies between 10% and 35%. The data is not suitable for imputation due to the small sample size. Multiple imputation methods are used on studies with samples greater than 100 (Yoo, 2009). Cases with missing data values have been excluded test-by-test to preserve the maximum amount of useable data. The size of the sample used in each calculation is provided.

Table 5.2 Summary of missing data

Name	Number of responses	Number of missing responses
Pre-Course Questionnaire	17	3
Course Questionnaire	20	0
Post-Course Questionnaire	19	1

#### 5.2.4. Analysis

Data from Likert scales are nonparametric and therefore the central tendency and variance statistics were calculated as Median (Mdn) and Interquartile Range (IQR).

To determine if there were statistically significant differences in the data collected before and after the course the nonparametric Wilcoxon Signed Ranks test was used. The Wilcoxon test is the nonparametric equivalent of the paired t-test (Brace, Kemp, & Snelgar, 2012). As the data is non-parametric and from a small sample size, exact test statistics have been calculated to ensure that the data meets the assumptions of the tests used (Mehta & Patel, 2013). IBM SPSS Statistics Version 22 was used to perform the statistical calculations.

The effect size,  $r$ , (.1 = small effect, .3 = medium effect and .5 = large effect) was manually calculated for the test of significance using equation 3.1. (Pallant, 2007, p. 225):

$$r = \frac{Z}{\sqrt{N}}$$

$r$  = effect size

$Z$  = test statistic

$N$  = the number of observations

5.1

### 5.3. Results

#### 5.3.1. Participants

The participant details are represented in Table 5.3. The final number of participants was 20 as there were 2 non-attendees on the course.

Table 5.3 Participant details

Participant No.	Teaching Status	First Degree
P1	Trainee	Creative arts & design
P2	Trainee	Creative arts & design
P3	Trainee	Creative arts & design
P4	Trainee	Creative arts & design
P5	Trainee	Creative arts & design
P6	Trainee	Creative arts & design
P7	Trainee	Engineering & technology
P8	Trainee	Creative arts & design
P9	Trainee	Librarianship & information science
P10	Teacher	Engineering & technology
P11	Teacher	Creative arts & design
P12	Teacher	.
P13	Teacher	.
P14	Teacher	Creative arts & design
P15	Teacher	Engineering & technology
P16	Teacher	Creative arts & design
P17	Teacher	.
P18	Teacher	.
P19	Teacher	.
P20	Teacher	.

### 5.3.2. Quantitative Results

Before attending the course participants were asked about their previous use of laser cutting technology in the classroom. The majority of participants had used laser cutters before (n = 16). Participants (n = 14) responded that they had received training in how to use the laser cutter. Few participants (n = 3) reported receiving any prior formal laser safety training.

The pre-course questionnaire asked participants whether they considered a laser cutter to be suitable for use in the different subject areas of D&T, Figure 5.2. All participants (n = 17) consider it suitable for Resistant Materials and Graphic Design. The areas of uncertainty are in Textiles (n = 1) and Electronics (n = 5).

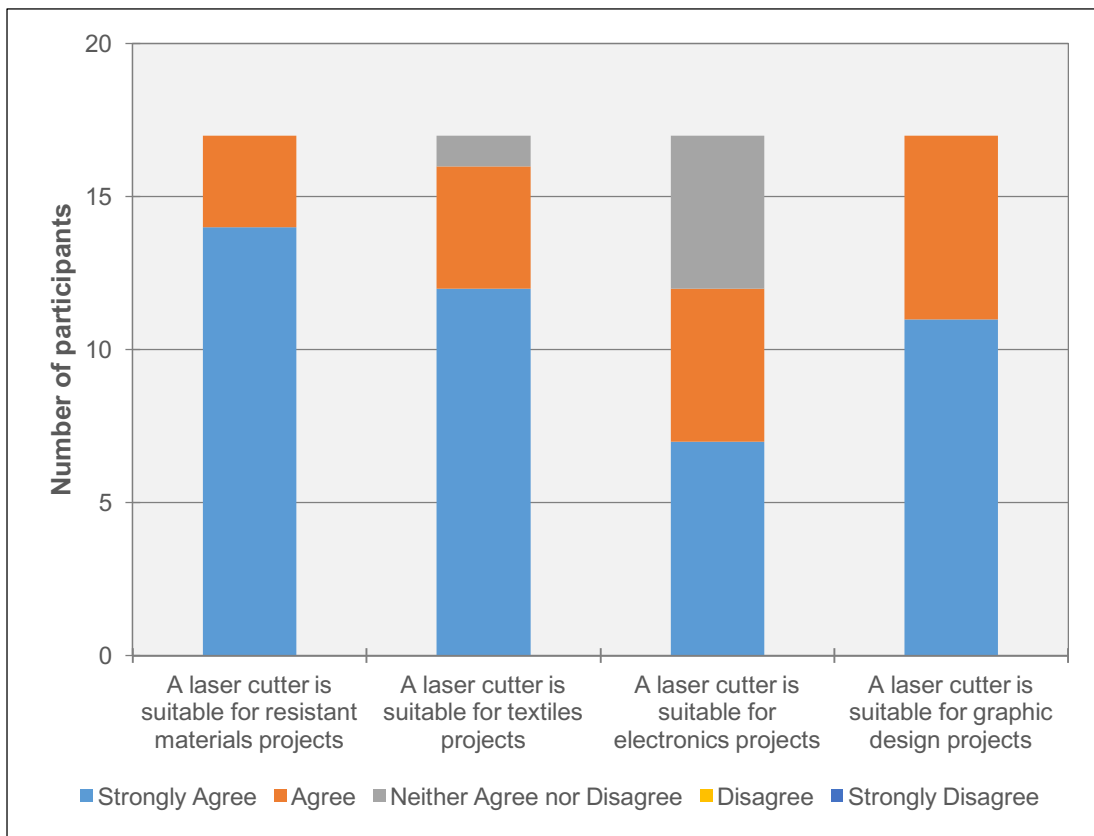


Figure 5.2 Suitability of laser cutter in different subject areas

Participants were asked in the pre-course and post-course questionnaires to score their answers to if their pupils/students should be allowed to use the laser cutter on their own on a 5 point Likert scale. The responses are shown in Table 5.4. Measures of central tendency were calculated to summarise teachers' opinion on pupils using laser cutters. Before the course participants thought that pupils should not use the laser ( $n = 17$ ,  $Mdn = 3$ ,  $IQR = 2$ ). Following the course teachers were positive about pupils using the laser ( $n = 19$ ,  $Mdn = 4$ ,  $IQR = 2$ ). A significant difference in pre and post course scores was found using a Wilcoxon Signed Ranks Test of 1-tailed exact significance ( $n = 16$ ,  $Z = -2.064$ ,  $p = .029$ ,  $r = .36$ ). The course was able to change teachers' opinion on letting pupils use laser cutters ( $p < 0.05$ ).

Table 5.4 Pupils' use of laser cutters

Likert Scale	Number of participants who rated "Pupils/students should be allowed to use the laser cutter on their own."	
	Before	After
Strongly Agree (5)	0	5
Agree (4)	6	6
Neither Agree nor Disagree (3)	5	3
Disagree (2)	3	3
Strongly Disagree (1)	2	1

Note: Measurements were taken before and after the teacher training course through the pre-course and post-course questionnaires respectively.

Participants were asked in the pre-course and post-course questionnaires to score their confidence in teaching the four main topics of the course to their pupils on a 5 point Likert scale. The responses are shown in Table 5.5. Measures of central tendency were calculated to summarise each of the measurements of teacher's confidence. Wilcoxon Signed Ranks Tests of 1-tailed exact significance were calculated to compare the scores for pre and post course measurements in the four areas of confidence.

There was no significant difference between the pre-course (Mdn = 3, IQR = 1) and post-course (Mdn = 4, IQR = 2) for the first question "I would feel confident teaching pupils about the technical capabilities of a laser" (n = 15, Z = -.998, p = .187, r = .18).

There was no significant difference between the pre-course (Mdn = 4, IQR = 1) and post-course (Mdn = 5, IQR = 1) for the second question "I would feel confident teaching pupils how to use the CAD software to produce designs for a laser cutter" (n = 16, Z = -.905, p = .281, r = .16).

There was a significant difference between the pre-course (Mdn = 4, IQR = 1) and post-course (Mdn = 5, IQR = 1) for the third question "I would feel confident teaching pupils how to use the laser cutter" (n = 16, Z = -1.903, p = .043, r = .34).

There was a significant difference between the pre-course (Mdn = 3, IQR = 1) and post-course (Mdn = 4, IQR = 1) for the fourth question "I would feel confident teaching pupils laser safety" (n = 15, Z = -1.838, p = .045, r = .34).



Table 5.5 Participants' confidence in teaching the course topics

Likert Scale	Number of participants who rated							
	I would feel confident teaching pupils about the technical capabilities of a laser		I would feel confident teaching pupils how to use the CAD software to produce designs for a laser cutter		I would feel confident teaching pupils how to use the laser cutter		I would feel confident teaching pupils laser safety	
	Before	After	Before	After	Before	After	Before	After
Strongly Agree (5)	2	3	7	9	4	9	3	5
Agree (4)	4	7	6	6	7	5	4	8
Neither Agree nor Disagree (3)	6	2	3	0	4	1	6	2
Disagree (2)	2	3	0	1	1	1	2	0
Strongly Disagree (1)	1	0	0	0	0	0	0	0

Note: Measurements were taken before and after the teacher training course through the pre-course and post-course questionnaires respectively.

There was a statistically significant positive change in teachers' self-reported confidence in teaching pupils how to use the laser cutter and laser safety ( $p < .05$ ). However, there was no significant change in teachers' self-reported confidence in teaching pupils the technical capabilities of a laser or in the CAD software used to produce designs.

The post-course questionnaire asked teachers to score the relevance of course content to include in lessons for their pupils. The summary descriptive statistics of central tendency and variance for these data are calculated in Table 5.6. Eight of the 12 questions have calculated median scores of Relevant (Mdn = 4).

Table 5.6 Teachers self-reported relevance of course content for pupils

In your own future teaching which aspects of the course would be relevant to include in your lessons for students?	n	Mdn	IQR
Industrial applications of lasers	15	4	2
How a laser works	15	4	1
The different types of lasers	15	3	2
Details of the optical systems and parts of the machine	15	3	2
How a laser beam interacts with materials	15	4	1
What materials can be processed by laser	15	4	1
Details of the laser drilling process	15	3	1
Details of the laser cutting process	15	4	1
Laser safety regulations and the different classes of laser.	15	4	2
The different hazards in a laser cutter and practical laser safety	15	4	1
The use of 3D CAD	15	4	1
Studying engineering at undergraduate level	15	3	2

Note: Rated on a 5 point Likert scale. 1=Very Irrelevant, 2=Irrelevant, 3=Neutral, 4=Relevant, 5=Very Relevant.

Participants were asked about their interest in attending similarly presented courses on other topics. The other courses proposed and the levels of interest are shown in Figure 5.3.

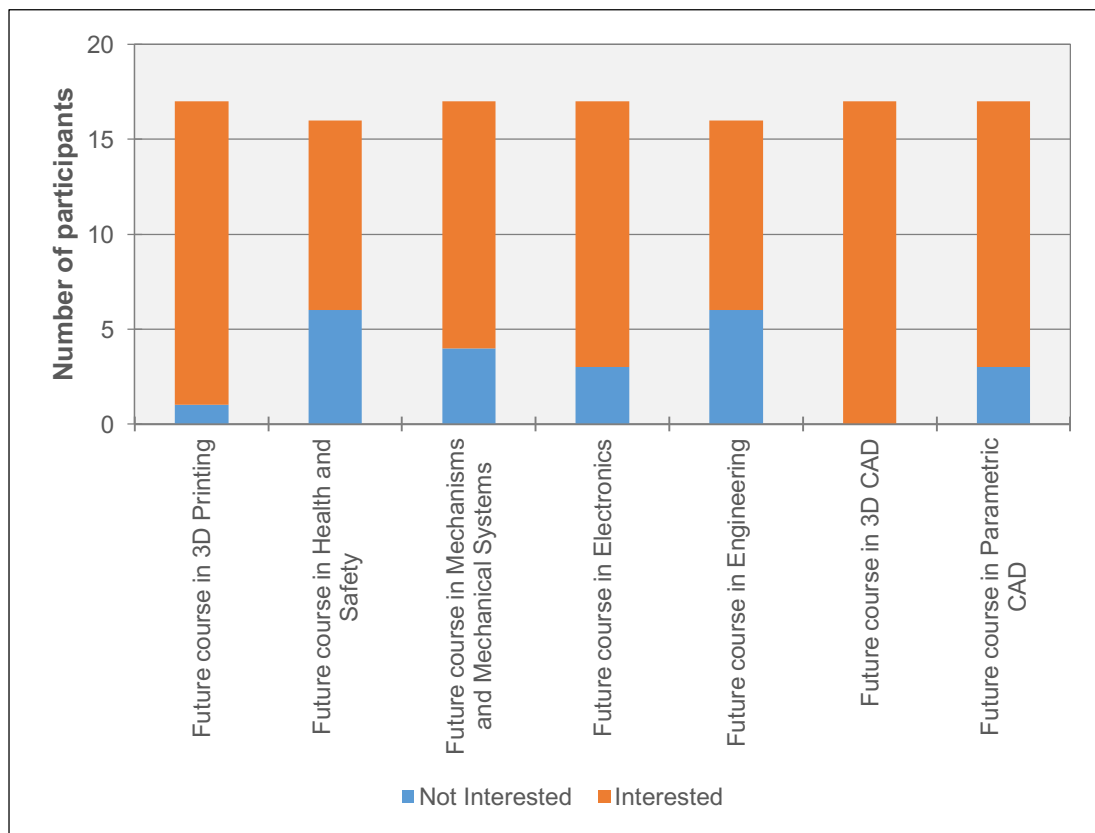


Figure 5.3 Participants interest in attending other CPD courses

During the course, questionnaires were administered and responses were collected using electronic voting systems to assess existing technical

knowledge, Figure 5.4, and to test participants learning of course laser safety content, Figure 5.5.

Questions 1, 3 and 4 in Figure 5.4 have the majority of participants with a correct answer ( $n > 10$ ). These three questions assess a basic understanding of the machine. Question 2 and 5 required a deeper understanding of the process and the number of correct answers are low ( $n < 10$ ).

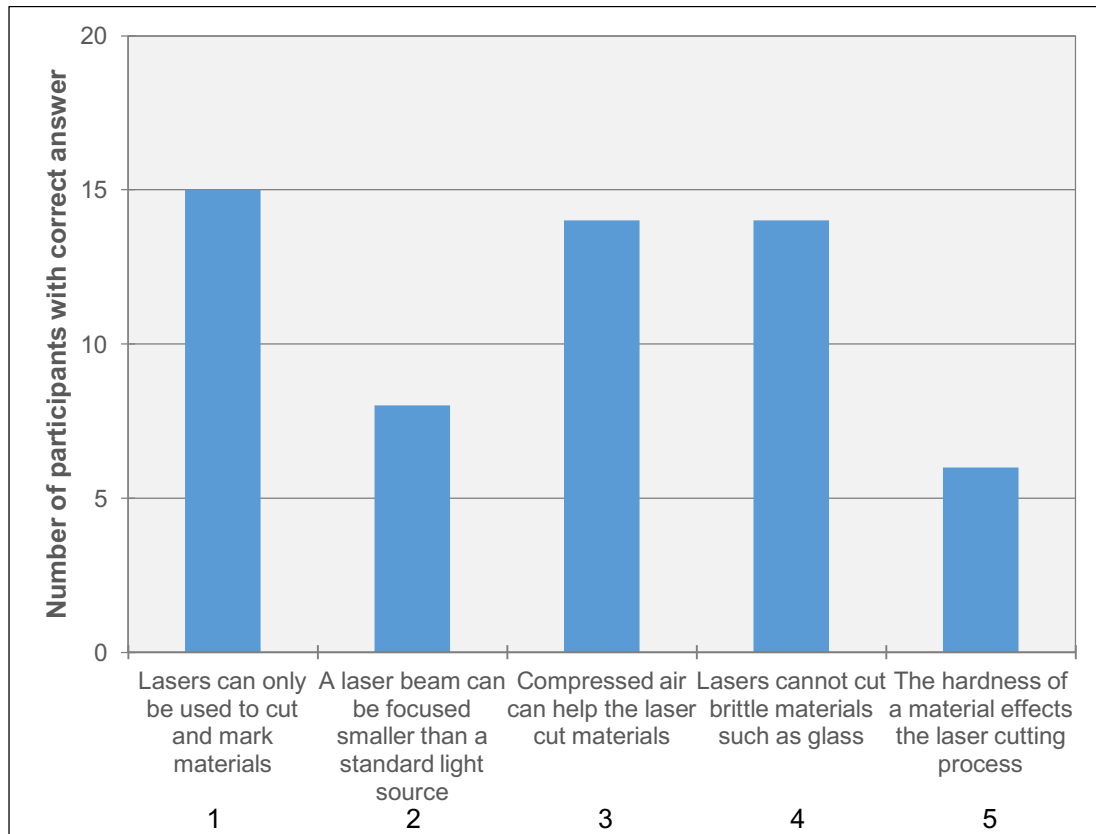


Figure 5.4 Course evaluation of technological knowledge

Eleven of the 13 items in Figure 5.5 had the majority of participants with the correct answer ( $n > 10$ ). This demonstrates a high level of understanding with the laser safety content.

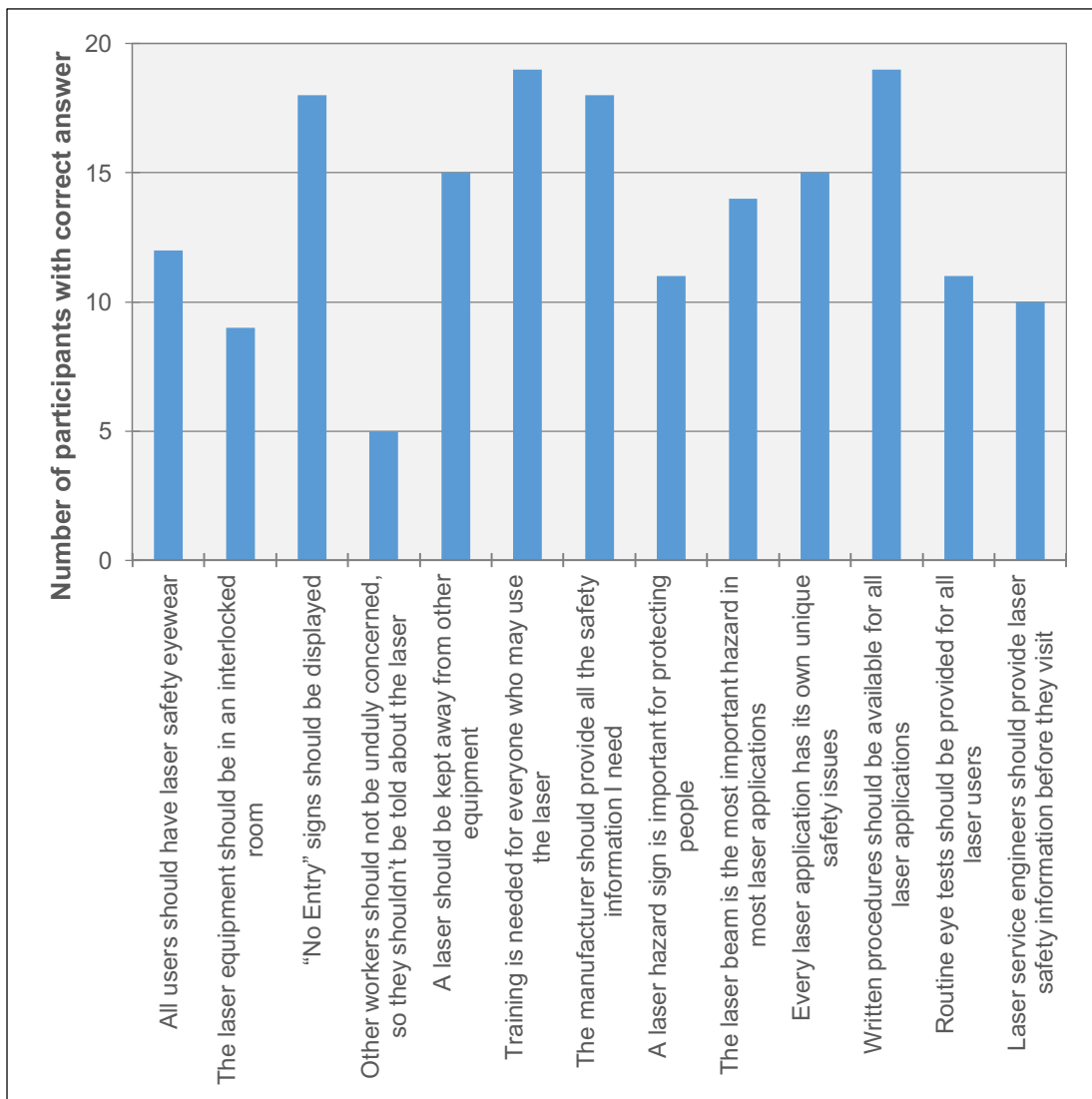


Figure 5.5 Course evaluation of laser safety learning

### 5.3.3. Qualitative Results

#### Results from Phase 1 Pre-Course Questionnaire

The open ended questions in the pre-course questionnaire focused on schools existing practice in using laser cutters and encouraging STEM education with pupils.

Participants were asked if they encourage or allow the pupils to use the laser cutter. The responses made by participants demonstrate that teachers do not allow their pupils to operate the machinery, and that a member of staff operates the equipment for the pupils:

*P3: "pupils design, technician cuts"*

*P13: "They [pupils] design there ideas I cut them out"*

The rest of the comments made by participants on the pre-course questionnaire were with respect to STEM content in D&T. Participants demonstrated uncertainty with teaching STEM in D&T. Participant 5 reported a lack of confidence in STEM teaching:

*P5: "Unsure of my own confidence in this area"*

Participant 10 stated that they try to include mathematics in D&T:

*P10: "Try to include this."*

This uncertainty demonstrated by the teachers also extended towards providing career advice for pupils. The teachers were unsure of the specifics of what was delivered in their school but demonstrated an opinion that it should be included:

*P7: "The school holds stem classes every week for year 7 8 but I am unsure of content"*

*P10: "This should be a focus for the school"*

### Results from Phase 3 Post-Course Questionnaire

Participants were asked for their opinion on the technical content covered in the course. This included the topics of the optical systems and parts of the machine and the processes that the machine performs. Two participants gave positive feedback on the level of technical content of the course and its relevance.

*P16: "The course was very interesting on a technical and theoretical level."*

*P8: "there was a lot of scientific information which was relevant but not simplified enough for pupils to understand or relate to."*

The comments made by participant 8 suggest that the participant was unsure of how to convert the content knowledge they had gained into pedagogical content knowledge in order to teach it to their pupils.

Participants also gave negative feedback on the technical content of the course. Two participants considered there to be too much technical information within the course:

*P5: "Too much information"*

*P4: “technical information in the morning went into far too much detail and went on for too long”*

Another two considered the level of the content to be too high for them to understand. This provides evidence towards the technological and scientific knowledge of teachers with a background in creative arts & design.

*P3: “the course was very thorough however some was pitched too high”*

*P4: “I know basic physics, but the information we were given was too specialist [...] I found most of the information irrelevant to what I wanted to understand”*

*P6: “There are some aspects of the laser training day that I found a little confusing. There was way too much science about lasers and not enough on the practical application of them. While interesting, it was not necessarily useful on all levels”*

Comments were made was about the level of the technical content for pupils. Participant 15 considered the content to be suitable for a higher age range than the course was intended to benefit:

*P15: “More for A level students”*

Similar concerns for pupils learning were made by another participant. This reflects the need to transform the content knowledge of the course into pedagogical content knowledge for its use in the classroom.

*P6: “[...] with more concern to how this knowledge can be translated to a classroom”*

The focus of the procedural knowledge aspects of using the laser cutter was laser safety. This area received positive feedback from three participants and corresponds to the evidence of technical safety learning presented above.

*P8: “Good safety information”*

*P6: “The safety of the machines and how they should be set up was interesting and very relevant.”*

The feedback from two participants reflected their desire for more focus on the procedural knowledge aspects of the machinery.

*P4: "I would've preferred to spend more time discussing laser cutting projects"*

*P13: "I would have preferred to have focused more on, getting the best use of our laser cutter, hints and tips on how to promote our department through the use of the laser cutter by enthusing our students in KS3 so that they choose our subject at GCSE with some amazing new ideas and ideas for projects."*

There were four negative comments made on the session regarding undergraduate engineering. The participants did not understand why the content was included in a course on Lasers or why it was given to D&T teachers

*P3: "I would also suggest that the discussion regarding engineering is removed as this isn't relevant."*

*P8: "This felt irrelevant to course on lasers."*

*P11: "Felt like a sales pitch and not what we had attended the course for."*

*P19: "Seemed a last minute addition"*

## **5.4. Discussion**

### **5.4.1. Suitability of the course**

Problems teachers faced when using laser cutters in school were identified in Chapter 4. A CPD intervention with teachers was chosen as the method to address these issues. Harrison (2011) identified the need for improvements in Technology and Engineering education through CPD for D&T teachers. As previously discussed, teachers do not have a specific set of content they must teach (Zanker, 2008), but laser cutters are one suitable form of the CAM technology they must teach as part of the National Curriculum (Davies & Hardy, 2015). The trainees in the sample were required to learn laser cutting as part of their PGCE ITT programme, the teachers in the sample were self-selecting and laser cutting was relevant to them as they had the technology in their schools.

The Minimum Competences for Trainees to Teach Design and Technology in Secondary Schools (Design and Technology Association, 2010) do include some competences about CAM. Relevant extracts of the competences are given below.

In Materials Technology the competences require teachers to make use of CAM and accurate manufacturing techniques. Teachers are also required to understand the details of material properties and their manufacture:

*“M.M.4.3 Accurately cut and waste, by using machines (e.g. centre lathe, vertical and horizontal milling), wood, metal, plastics to efficiently achieve precision fit and quality finish.”*

*“M.M.3.6 Make use of CAM prototyping to fully realise small product prototypes (e.g. rapid prototyping, laminate assemblies).”*

*“M.K.4.1 Consider and analyse the physical, chemical and working properties at a micro level of a wider range of woods, metals and plastics (including modern and smart materials), and how the micro arrangement of particles and fibres in the material influence macro properties.”*

*“M.K.4.2 Understand, at a micro level, how materials can be combined and processed to create useful properties (e.g. the principle of composite materials).” (Design and Technology Association, 2010, pp. 19, 21)*

In Textiles Technology, laser cutters are specifically mentioned as a suitable technology to use:

*“T.D.3.7 Use CAD/CAM to enhance fabrics (e.g. embroidery software and hardware, draw and paint packages for stencils, transfer and sublimation printing, laser cutting).”*

*“T.K.4.3 Show understanding of industrial processes and technological fabrics and finishing fabrics including use of advances in CAD/CAM.” (Design and Technology Association, 2010, pp. 24, 26)*



The National Curriculum (Department for Education, 2013a) specifies what pupils must learn in KS3 D&T. The follow extracts are relevant to the course content:

*“select from and use specialist tools, techniques, processes, equipment and machinery precisely, including computer-aided manufacture”*

*“select from and use a wider, more complex range of materials, components and ingredients, taking into account their properties”*

*“understand and use the properties of materials and the performance of structural elements to achieve functioning solutions.”* (Department for Education, 2013a, pp. 2–3)

The National Curriculum and the D&T Association minimum competences justify the reasons for the inclusion of technical and scientific content within the course. The content of the course was designed to develop a deep understanding of the technology within the participants to enable them to achieve these competences.

The suitability of laser cutters in D&T is validated by participants’ opinions on its use in the different subject areas of D&T. Participants considered this technology is useful in all areas of the D&T curriculum, and this reflects the wide range of industrial applications for laser materials processing.

The benefit of delivering such a course at a higher education engineering institution was apparent from the positive response to modern engineering education methods, including access to the engineering teaching laboratories. The course was able to attract a range of teachers during their holidays, who had little prior understanding of the general or specialised engineering content covered in this course and there was significant interest in teachers returning to study other technologies.

#### **5.4.2. Use of laser cutters**

The findings suggest that teachers know enough to be able to operate the machinery and understand that it can be used in all areas of D&T. However, there is evidence of a lack of deep understanding on the part of the teachers which may limit its use in the classroom.

Before the course, the teachers were asked if pupils should be allowed to use the laser cutter on their own. Only 6 participants thought that pupils should be allowed to use the laser cutter. This demonstrates that a lack of teacher knowledge in these specific technologies is limiting pupils' opportunities to use the equipment. With appropriate health and safety precautions in place pupils can safely operate laser cutting machinery. Unnecessarily restricting interaction with technology will have a negative impact on pupil learning and motivation.

#### **5.4.3. Concerns of teachers**

The results identified three themes of concerns that participants had with the course. These three concerns transition through the three stages of Fuller's (1969) concerns model of teacher development. In this section the three concerns will be discussed:

- Concerns about self; the level of the technical and scientific content and teacher confidence in teaching it.
- Concerns about self as teacher; transformation of the content knowledge in the course to pedagogical content knowledge.
- Concerns about pupils; the relevance of the content for delivery to pupils.

#### Concerns about self

This study aimed to improve teachers' technological subject knowledge through a 1 day CPD course. One measure of this was the comparison of participants' confidence in teaching the technical content covered in the course.

During the lectures the participants' prior level of technical knowledge was assessed through questions about laser cutting. The results show evidence of a basic understanding of the equipment and what it is used for, but not a deep understanding of the process. This result was in alignment with the comparison of confidence in technical teaching.

No significant change in participants' confidence in teaching pupils' technical conceptual knowledge is an unexpected result. Much of the time during the course was intended to develop teachers' technological knowledge. This may be explained by a combination of factors. The amount and level of technical

content that delivered was too high for the participants. Over half of participant's background specialism, measured by their prior degree, was in creative arts and design (n = 10). Participants may not have sufficient background knowledge in technical areas. This matches conclusions drawn in previous chapters. Trimmingham and Horne (2008) suggested that lack of 'base' understanding was the reason for lack of confidence in technical teaching in their CPD course.

The conceptual technical knowledge taught at the start of the course contained science concepts. The inclusion of science and physics knowledge was specifically identified as a difficulty by participants. The quantitative and qualitative evidence suggests that teachers are not confident with science concepts.

Participants did make significantly measureable progress in the procedural technological aspects of using the laser cutter. Participants have made improvements in the subject areas with which they are more comfortable. They remain resistant to the more challenging technology elements of the course.

The topic of laser safety was the most successful area of learning in the course, achieving the largest improvement in teacher knowledge and potential teaching impact. With 8 participants reporting an improvement in their confidence in laser safety teaching. This was achieved through the teaching of laser safety in lectures and then further demonstrations of laser safety during the laboratory sessions. The positive effect of the laboratory demonstrations was reported in the participant feedback.

#### Concerns about self as teacher

The literature review identified the importance for teachers to develop their knowledge into a form suitable for teaching, Pedagogical Content Knowledge (Ball et al., 2008; Turner-Bisset, 1999; Turnuklu & Yesildere, 2007). The qualitative feedback identified that the participants considered the knowledge delivered in the course was not in a format appropriate for pupils. These comments highlight the problems teachers had in transforming the new technology and content knowledge given in a format for them into a form appropriate for their pupils. Pupil learning is enhanced when teachers are

able to transform their knowledge of technology into teaching practice (Moreland & Jones, 2001).

This suggests that the amount of technical content should be adjusted and additional time is required to adapt the technical content delivered into technological pedagogical knowledge and pedagogical content knowledge. Based on feedback this should include time for teachers to discuss implementing these practices and sharing their knowledge and experience and the facilities to be able to share their new teaching practices developed after the course. Other CPD courses for D&T have used these activities to develop teachers' pedagogical knowledge, however more time is required (Trimingham & Horne, 2008).

Participant feedback suggests that they cannot comprehend the use of, or demand for this technical information. A future course would therefore aim to explain to teachers that we are not just improving the teachers' knowledge of laser cutting but that the information is applicable in other areas and that the broader technical knowledge is desirable in pupils.

#### Concerns about pupils

There were divided opinions on the relevance of the course content for pupils. Participants were requested to rate the relevance of the course content for their pupils. There were positive participant responses to the relevance of topics about industry, materials and the cutting process. However, participants did not consider all of the topics to be relevant to pupils. The broader topics connected to the area, which included more science content, such as the types of lasers, details of the optical systems and the laser drilling process were not considered to be relevant to pupils. The participants appear to consider the topics with a higher level of scientific and conceptual technological content not relevant to pupils. The opinion of the participants may be because a discussion of the delivery and value to pupils was not included. It may be necessary to explain to teachers the potential benefits to pupils in education and post-school. Teachers engagement and motivation with the content is critical as there is a positive link between pupil motivation and teacher motivation (Atkinson, 2000a). Personal motivation towards a CPD topic was shown by McMillan,

McConnell and O'Sullivan (2014) to be the principal factor in CPD engagement.

The session on studying engineering at undergraduate level was intended to provide participants with information about why the technical content of D&T is important and what it enables pupils to achieve after school. Based on the demographic profile of teacher created in Chapter 3 it was thought that this session would be necessary as the majority of D&T teachers do not have a background in engineering and technology. This is also evident in the sample used in this study. This session was also considered not to be relevant by the participants and was specifically mentioned as irrelevant in the qualitative feedback. This evidence suggests a lack of understanding about what engineering is. The participants appear to only consider the use of technology in isolation and not the integration of technology into other curriculum areas or the purpose beyond the D&T classroom.

As previously discussed the topic of laser safety showed evidence for the best improvement in participants teaching confidence. This topic was also considered to be relevant for pupils. This suggests a link between the deep understanding of the content and the relevance teachers hold to pupil learning.

Participants reported that level of technical content was only appropriate for older pupils. This would have to be addressed as it is important that KS3 pupils can be motivated at an age where they can choose appropriate subjects as they progress through education.

#### **5.4.4. Limitations**

The large number of items in the pre and post course questionnaire may have resulted in missing data, and the inability to conduct some statistical techniques. A smaller number of items developed to analyse specific factors should be used.

The questionnaires used in this study utilised self-report measurement techniques. Podsakoff, MacKenzie, Lee, and Podsakoff (2003) and Spector (2011) present and discuss the limitations of this method:

- Participants write what they think is socially the correct answer to sensitive information,

- 50 to 80 percent of method variance may be produced by sources other than the intended,
- Participants try to maintain consistency with their answers, which produces relationships,
- Participants respond with their own implicit theories,
- The mood of the participant at the time of completing the questionnaire. (Podsakoff et al., 2003; Spector, 2011).

More detail about each individual participant should have been collected in order to add contextual information to the qualitative comments collected and presented as results. This would provide better validation of the comments given by participants. This was addressed in the collection of data in the following study.

## **5.5. Summary and Conclusions**

This was a content focused study where teacher learning is considered to be the most influential feature of the CPD activity (Desimone, 2009). Following Desimone's (2009, 2011) model, increases in teacher knowledge and skills may lead to institutional changes and improved student learning.

It was expected that the teachers would not start with a deep understanding of laser cutting, which is subsequently why they attended the course. This was confirmed in the results. Participants' confidence in teaching the content associated with laser cutter use was measured before and after the CPD intervention. There was no measured improvement in the technical concepts covered in the course. This is linked to the participants' rating of the relevance of the course content to pupils, whereby technical concepts were not considered relevant to pupils.

The present work concerning the application of computer controlled laser cutting machines identifies a lack of technological knowledge and skill improvement in some secondary school D&T teachers. It also provides evidence to support the proposition that the teachers' background knowledge and experience can limit the activity and breadth of student experience.

Although information was delivered through the same short course about the technical and scientific aspects of the technology, there was limited

improvement in teacher confidence in the post-course evaluation in these factors. This problem is associated with the limited technological background that many of the participants brought with them. There is a need to explain the general nature of engineering to these teachers as they did not understand the need to teach engineering in schools as either a subject in its own right or as a core field of study within the STEM subject curriculum

The findings present evidence of the participants understanding of the relevance for the technological content. The participants can be described as being unconsciously incompetent (Robinson, 1974) with respect to the technical and scientific aspects of the technology in their classroom; this is the first of four stages in developing competence in an activity (Chapman, n.d.; Dodgson, 1987; Robinson, 1974). The conclusion is linked to the demographic analysis of D&T teachers conducted in Chapter 3. In this instance the teachers do not have enough of a technical background to understand the landscape and purpose of the technology they are trying to teach. Methods for addressing this issue in a CPD course have been discussed.

## **6. Studying the implementation of a range of new technology resources by D&T teachers**

### **6.1. Introduction**

The study in chapter 4, of one new technological project tested in depth, identified the difficulties trainee teachers faced in adopting technological resources due to the limitations of subject knowledge. It was a small sample of 4 trainees from one institution. To validate the study's findings, the examination of a wider spectrum of technology resources was required, using a more representative sample of teachers. Recommendations were also made to study the impact on pupils. Chapter 5 analysed teachers' opinions and knowledge outcomes from attendance on one CPD course. From this, there is the requirement to study and analyse teacher understanding and learning for a broader range of topics.

This chapter presents the work contribution of the author to the findings from the "STEM into Action with D&T" project funded by the Mayor of London's Education Programme: London Schools Excellence Fund (London Schools Excellence Fund Reference: LSEFR1210). This project was created and developed by The D&T Association in partnership with Mindsets, a provider of D&T resources. The project ran between January 2014 and September 2015. Teaching activities in schools took place in the 2014/15 academic year. The author was commissioned to develop the research methods, conduct the enquiry and analyse the finding for the work conducted in these schools. The project provided an excellent opportunity to create a study of a more representative sample of teachers engaging with a variety of CPD activities and resources.

#### **6.1.1. Overview of the "STEM into Action with D&T" project**

The purpose of the "STEM into Action with D&T" project was to provide 100 London schools with a range of free resources for D&T teachers to improve their STEM teaching.

The aims of the "STEM into action with D&T" project proposed by The D&T Association were to:



- prepare teachers for the introduction of the new National Curriculum in September 2015 by developing a range of resources and associated CPD to address teachers' knowledge and experience gaps, while enhancing existing skill levels and helping to develop confidence;
- create a network of centres of excellence that will support local schools using peer-to-peer methods;
- ensure STEM teaching keeps abreast of emerging technological developments;
- demonstrate that D&T underpins the delivery of STEM in the classroom;
- motivate pupils to explore STEM concepts through a range of engaging activities and projects that are 'real world' and relevant;
- encourage more pupils to consider future qualifications and careers that use STEM concepts in an applied context.

The teachers in the schools taking part in the project chose from a range of 57 resources, all created by Mindsets, see Appendix C - List of "STEM into Action with D&T" project resources. The resources available to teachers contained Practical Packs based on kits of parts that allowed pupils to build technology-based products such as LED lamps, Smart Phone Kaleidoscopes, E-Textiles, Fridge Magnets and Smartcord wristbands. Also available were World of Materials Tutorial packs containing materials and worksheets to teach pupils about topics such as thermochromic materials, memory metals, photochromic materials, glow-in-the-dark materials and composite materials. All resources were created for KS3 pupils.

This chapter provides an analysis of data generated to address a subset of aims (below) for the project. This chapter is concerned with the data generated during project delivery schools to analyse the confidence levels of teachers and to assess pupil motivation.

### **6.1.2. Aims of the study**

The specific aims of this study were to:

- Evaluate any changes to KS3 pupils' ability and motivation in technology education resulting from these new resources.
- Assess teachers technological teaching competence for the latest version of the National Curriculum.

## **6.2. Methods**

### **6.2.1. Sampling**

The resources and support were available to schools in London. The project was set up by The D&T Association and consisted of two phases, involving two sets of schools. In Phase 1, pilot schools led by exemplar schools, teachers would develop their own schemes of work from the resources, test teaching of the schemes of work and develop an evening session for other teachers to attend in which they would share the successes of their work. These evening sessions were named twilight sessions and were the peer-to-peer method of CPD used throughout the project to support the resources. In Phase 2 the teachers from main schools would attend twilight sessions and select and develop their own schemes of work from the resources and CPD provided. Both sets of schools took part in the questionnaire process.

#### Set 1 – Exemplar and Initial Pilot Schools

The 4 'Exemplar Schools' each worked with up to 5 'Initial Pilot' Schools. The target sample size was 24. The total achieved was 21 for set 1. These schools were selected by the D&T Association specifically as they were known to be the most capable and able to develop the extra work required during Phase 1. The 4 exemplar schools were geographically distributed around London. To ensure a wide coverage of the different areas of the city and to eliminate any overlap between the potential initial pilot schools working with the main schools. Each exemplar school was provided with their choice of £600 of resources. Each Initial pilot school was provided with their choice of £400 of resources. The schools in Set 1 were provided with more resources than the schools in Set 2 as they were expected to test more projects and develop twilight sessions.

#### Set 2 – Main Schools

This set was randomly selected by the D&T Association from secondary schools in London. There was available funding to provide resources to 80 schools. A total of 78 schools registered for the project. However, before teaching of the resources began 5 schools officially withdrew and 12 schools ceased communication with the project officers. The total was 61 schools in Set 2. Each main school was provided with £200 for their choice of resources. The teacher responsible for the project in each school was

expected to attend twilight sessions. Sessions aims were to learn about how to use the resources from other teachers, deliver two new projects, complete questionnaires during delivery and upload evidence of the project as a teaching showcase.

### Sample Power

To determine the sample size necessary for this study, a power calculation was undertaken. Population data for the total number of state funded secondary schools was available from the Department for Education (2015c) (N = 479). Sample size required for this population was calculated using equation 3.1. The sample size required was calculated as 59 (confidence interval 10% at 90% confidence level). The sample size for the study was 61 schools and was suitable at 90% confidence level.

### Reasons for withdrawal of schools

Eight teachers provided reasons for their withdrawal from the “STEM into Action with D&T” project. Four of the schools were withdrawn due to health issues and missing members of staff. The reasons for the withdrawal of the other four schools are presented below.

*“I have some sad news regarding the project. I have received a 3 for my appraisal and our results have been extremely poor. For this reason I have been asked/advised not to partake in additional workload as they want me concentrating on my core duties.”*

*“Our school has been expecting an Ofstead inspection and has been in limbo for the past two years as we wait, (we are currently overdue). This has put an extraordinary amount of pressure on our staff body as we are currently striving for an outstanding grade should Ofstead arrive. This has meant that many projects have had to sadly be dropped and I am afraid that I don’t think that my faculties involvement within the STEM project this year is viable. Given that I have found it difficult to facilitate this up to now, almost half way through the academic year, I also don’t think that I have supported the project in a way you nor I would like either. I would like to be involved however in future and ask that we are considered for any STEM activities next academic year.”*

*“I do not feel that I am able to complete the questionnaire. We have not had much success with the project that we were developing using Mindset resources. We have decided not to continue with the project.”*

*“I didn't see the applicability of the projects in Food Technology and Catering. I saw the projects to be more applicable in Graphics, Construction and Textiles. As a Food Technologist, I did not see how the electronics was going to benefit me. This is the reason why I decided not to proceed with the project.”*

### **6.2.2. Procedure**

#### Phase 1

Phase 1 involved the use of Set 1 to pilot the resources in schools. Support was provided to the schools in Phase 1 through 4 D&T expert teachers, selected by The D&T Association, who would act as Project Officers to the pilot schools. The aim of this phase was for teachers to develop and test the resources in their classes and use this experience to develop and run a peer-to-peer evening training sessions (Twilight Sessions) with the teachers in Sets 1 and 2. This phase was conducted entirely by The D&T Association.

Each of the teachers in Set 2 was expected to attend at least one of the twilight sessions offered by Set 1. This was to provide CPD activities for all the schools in the project and to help the teachers in Set 2 to select their resources.

#### Phase 2

A key part of the work done for this study was the development of questionnaires for pupils and teachers. The questionnaires were distributed and collected by The D&T Association. The questionnaires requested that the teacher complete the start of project questionnaire before teaching began.

Teachers would deliver two different projects to two different classes of their pupils. Teachers were responsible for administering the start of project pupil questionnaires during the first lesson using that resource. The pupils were numbered by the teacher to ensure that the before and after results of each individual could be compared. The use of numbering by the teachers was to ensure that no personal pupil information was gathered by the

questionnaires, and to allow pupils who chose to participate to remain anonymous.

Following the completion of the questionnaires for both the teacher and their pupils the schemes of work developed by the teachers using the resources were delivered.

### Phase 3

At the end of the lessons using the project resources the teacher administered the end of project pupil questionnaire to their pupils. Using their numbering system to ensure that each pupils individual progress could be measured. After completing the teaching and questionnaires of both groups the teacher was requested to complete their end of project questionnaire. All of the questionnaires were then returned by post to The D&T Association. Following analysis of the questionnaires a follow up question was sent by email to the schools who successfully completed and returned their questionnaire packs.

### Phase 4

After the completion of all teaching in the school, the participant teachers were requested by The D&T Association to submit evidence of their work in schools to the project website.

### **6.2.3. Design**

The previous studies in Chapters 4 and 5 informed the design of this study. This was the selection of appropriate methods, and the development of items on questionnaires to address limitations in the previous studies.

The study followed a quasi-experimental design (Wilson, 2009). Although the main schools were selected randomly the pupils were selected by teachers and were already pre-sorted into their classes. No separate control groups were used within the schools. Measurements were made of the pupils' and teachers' attitudes before and after the teaching intervention.

The data generation methods were split into the assessment of pupils' attitudes towards the new projects and the assessment of teachers' development. The pupils were assessed entirely through quantitative questionnaires. Teachers were assessed through questionnaires that contained both quantitative and qualitative questions.

### Design of Pupil Questionnaire

Quantitative questionnaire analysis was selected for the pupils as the project had the potential to generate data from over 1000 pupils. It would have been unfeasible to gather large amounts of qualitative data from such a large sample.

The aims of the “STEM into Action with D&T” project, see section 6.1.1, and the study, see section 6.1.2, were to assess the motivation of D&T pupils. Self Determination Theory is a broad framework for the theory of motivation that was established by Deci and Ryan (1985). It introduced the idea of intrinsic and extrinsic motivation. In education intrinsic pupil motivation is learning for their own benefit, while extrinsic motivation is driven by the desire to pass exams (Deci & Ryan, 2000; Ryan & Deci, 2000a, 2000b). Intrinsic motivation is associated with better academic performance in school (Cordova & Lepper, 1996; Gillet, Vallerand, & Lafrenière, 2012; Kusrkar, Ten Cate, Vos, Westers, & Croiset, 2013; Lin, McKeachie, & Kim, 2003; Uyulgan & Akkuzu, 2014). Links have also been shown between deep learning and intrinsic motivation (Chin & Brown, 2000; Marton & Säljö, 2005; Warburton, 2003).

To assess the motivation of pupils in this study the Intrinsic Motivation Inventory (IMI) was used, (<http://www.selfdeterminationtheory.org>). The IMI questionnaire is a multidimensional instrument containing subscales of interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, perceived choice while performing a given activity and experiences of relatedness. The instrument has been used in prior research (Deci, Eghrari, Patrick, & Leone, 1994; Plant & Ryan, 1985; Ryan, Connell, & Plant, 1990; Ryan, Koestner, & Deci, 1991; Ryan, 1982) and specifically in measuring pupils in educational research (Loukomies et al., 2013; Sproule et al., 2013; Vaino, Holbrook, & Rannikmäe, 2012).

Three of the subscales were chosen for use in this study interest/enjoyment, perceived competence and pressure/tension. The interest/enjoyment subscale is the self-report measure of intrinsic motivation and contains 7 items. The perceived competence subscale is a positive predictor of intrinsic motivation and contains 6 items. Pressure/tension is a negative predictor of intrinsic motivation and contains 5 items. It is expected that there will be

correlation between the factors and to provide validation between factors. The original IMI questionnaire is generic and it recommended by the authors of the instrument that it is modified to suit the individual study. The questionnaire has therefore been modified so that the items assess pupils' perceptions of technology projects in D&T. Below is an example of one modified item:

- Original statement: "I thought this was a boring activity"
- Modified statement for start of project: "I think that technology projects are boring."
- Modified statement for end of project: "I thought that this technology project was boring."

The use of multiple items will improve the reliability of the three subscales. Pupils rate their agreement to each of the 18 items on a 7 point Likert Scale (1 = Disagree Very Strongly, 2 = Disagree Strongly, 3 = Disagree, 4 = Neutral, 5 = Agree, 6 = Agree Strongly, 7 = Agree Very Strongly). Some of the items in the questionnaire are negatively phrased and so are scored in reverse during the analysis. This is to improve the reliability of the multi-item factors. The questionnaire was administered by teachers to their pupils at start and end of the projects in school.

The questionnaire was piloted before its use by teachers in schools. The respondents to the pilot reacted negatively to the ordering of the items in the questionnaire as they were aware of the multiple items trying to assess the same factor. To address this, the questionnaire items were randomised. The final questionnaires given to pupils are shown in Appendix D.

#### Design of Teacher Questionnaire

The teacher questionnaire was composed of 6 sections and was given to the participant teacher at each school. Sections 1, 2 and 3 were completed by participants at the start of the project, and sections 4, 5 and 6 were completed by participants at the end of the project.

Section 1 requested participant teachers to give non-identifiable personal information and data about their teaching experience. The questions requested the individuals gender, first degree, route for ITT, number of years

teaching experience, position of responsibility, amount of technical CPD and if their colleagues are supporting them on this project.

Section 2 requested participant teachers to rate their agreement to 25 statements about their confidence in teaching the technical content of the national curriculum. Their confidence was rated on a 7 point Likert scale (1 = No Confidence, 2 = Unconfident, 3 = A little unconfident, 4 = Neutral, 5 = A little confident, 6 = Confident, 7 = Complete confidence). For each item participants were also requested to state if they had taught the item before. This section aimed to generate a score for teachers' confidence in teaching technical content before the start of the project and would be used in comparison to the score after the project in Section 4.

Section 3 requested participant teachers to rate their agreement on a 7 point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree) to the statement "It may be argued that in order to provide the best educational experience to pupils D&T teachers should collaborate with colleagues from different disciplines in the application of STEM within D&T projects."

Teachers were then requested to state if they had collaborated with colleagues from mathematics or science on a D&T project. The aim of this section was to measure participants' opinion on STEM collaboration.

Section 4 was identical to Section 2 and was completed following the delivery of the projects by the participant teacher.

Section 5 requested teachers to state which methods of CPD they would attend. They were allowed to select any of the following options:

- Video and Paper guides (to teach yourself)
- Online guides (to teach yourself)
- Demonstrations and discussion from other teachers
- Short (1 Day) courses
- Accredited courses from a university that will lead to a recognised qualification

Section 6 requested participants to describe the best and worst aspects of the project they encountered. This was to gain positive and negative



qualitative feedback on the project and to identify any other important outcomes that would not be discovered by the closed answer questions (Steele, 1995).

The aim of the study in this chapter was to assess teachers' technological teaching competence for the latest version of the National Curriculum. Section 2 and 4 of the questionnaire were designed to assess teachers' competence in delivering technology areas of the National Curriculum. The competence statements were derived from The D&T Association's D&T Progression Framework (Design and Technology Association National Curriculum Expert Group for D&T, 2014). This framework utilises statements from the National Curriculum D&T programmes of study for KS3 and additional points identified by the Design and Technology Association. The technical knowledge statements were selected by the researcher from the following categories of the progression framework: Technical Knowledge, Making products work; Making, Practical skills and techniques; Designing, Generating developing modelling and communicating ideas. These statements have been selected for this work to represent the technology competences of a D&T teacher, as they should be able to deliver all of these areas to their pupils.

Williams (2008) discovered that respondents to questionnaires disliked being asked to rate their competence, and preferred to be asked to rate their confidence. Williams used the self-reported measurement of confidence as a proxy competence. Hargreaves, Comber and Galton (1996) also found a relationship between self-reported competence and confidence on questionnaires for primary school teachers. Likert scales have been used to assess confidence in participants (Garbett, 2003; Pritchard, De Lusignan, & Chan, 2002). In the study of nursing confidence and competence by Stewart et al., (2000), confidence, rather than competence, is considered to reveal if participants will actually perform a task. Following the methods from prior research, the participants in this study were asked to rate their confidence in teaching the identified competences. The final questionnaire used in the study may be found as Appendix E.

To further explain the problems encountered by teachers implementing the resources a single follow up question was sent out to all questionnaire

respondents. The question was “What are the difficulties you face in delivering the D&T curriculum you want to teach?”. The question was developed to reveal further detail about the pressures on teaching that were identified in the questionnaire analysis.

#### **6.2.4. Analysis**

All data generated by the pupil and teacher questionnaires were input and processed by the author. The quantitative and qualitative analysis techniques used in this study were selected and conducted by the author.

##### Pupil Data

A factor analysis of the questionnaire responses was calculated first to verify if the 18 items in the questionnaire were measuring the 3 expected factors of the IMI that were selected (Tabachnick & Fidell, 2001). Factor analysis was used to investigate if there was structure in the pattern of correlations between variables, this analysis expects to determine if the 18 items measured actually represent the 3 subscales of Interest/Enjoyment, Perceived Competence and Pressure/Tension (Brace et al., 2012).

Before conducting the factor analysis two calculations were used to determine the suitability of the data for factor analysis. The Kaiser-Meyer-Olkin Measure of sampling Adequacy is used to test the amount of variance within the data that could be explained by factors, values above 0.6 are considered acceptable. Bartlett's test of sphericity tests that the data is factorable if significant. Passing these two tests suggests suitability of the data for factor analysis (Brace et al., 2012).

There are two common methods of Factor Analysis, Exploratory Factor Analysis (EFA) and to Principal Components Analysis (PCA) (J. D. Brown, 2009c; Tabachnick & Fidell, 2001). Tabachnick and Fidell's definition of factor analysis methods are:

*“...statistical techniques applied to a single set of variables when the researcher is interested in discovering which variables in the set form coherent subsets that are relatively independent of one another. Variables that are correlated with one another but largely independent of other subsets of variables are combined into factors”* (Tabachnick & Fidell, 2001, p. 582)

Exploratory Factor Analysis (EFA) methods were best suited to the items in this study; as the items in the questionnaires were developed on theory from previous research (J. D. Brown, 2009b). To achieve optimal results Costello & Osborne (2005) recommend the use of the maximum likelihood EFA method, that was available within IBM SPSS Statistics.

To make the pattern of loadings for each factor clearer rotation methods are required to analyse EFA data; oblique and orthogonal rotation methods maximise high correlations and minimise low ones. The oblique Oblimin with Kaiser Normalization rotation method was selected as there is expected correlation between factors (Tabachnick & Fidell, 2001). Oblique rotation is also favourable as it can reproduce orthogonal solutions (Costello & Osborne, 2005).

*A priori criteria* were used to extract 3 factors, this is based on the number of expected factors found in previous research using this instrument (J. D. Brown, 2009a). Only factors with a loading greater than 0.32 are interpreted as this is the threshold for 10% overlapping variance (Tabachnick & Fidell, 2001). The structure matrix has been used to interpret factor loading as it accounts for correlations between factors (Brace et al., 2012), the alternative pattern matrix may appear to show no loading as it only shows unique variance once overlap of correlations are omitted (Tabachnick & Fidell, 2001).

Following the EFA the reliability of each identified factor was tested for internal consistency using the calculations for Cronbach's alpha coefficients. Cronbach's alpha was calculated for each factor with values greater than 0.7 being accepted (Brace et al., 2012; Gliem & Gliem, 2003).

If the factor passed the tests for reliability then, following the instructions for using the IMI, the factor scores are calculated as the mean score for all the items in that factor. These factor scores have been used in the analysis of results. Box plots and non-parametric central tendency statistics were calculated to present the start and end results of the factors. The box plot displays median, interquartile range and range statistics for data. The features of a box plot are shown in Figure 6.1. In SPSS outliers are calculated at 1.5 x interquartile range; extreme values are calculated at 3 x interquartile range. Box plots were selected as the most appropriate method,

compared to histograms or tables, for the display of these statistical calculations. The box plots provide clear comparison of statistics between the factors calculated by observation of the movement of the box.

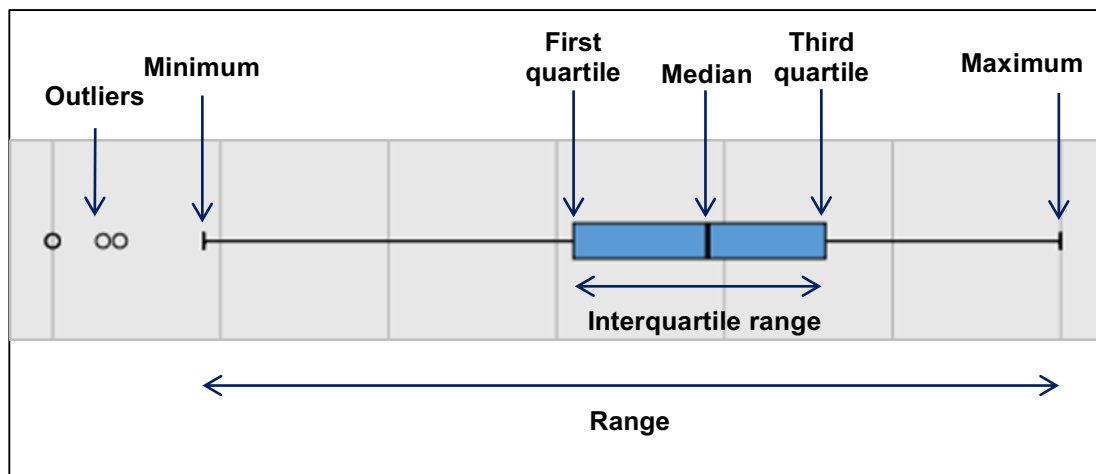


Figure 6.1 Features of a box plot

These collected data are best suited to analysis with the same non-parametric methods as used in Chapter 5. Wilcoxon Signed Rank Tests were used to compare the start and end of project results for each factor and assess if there were any statistically significant differences in results (Brace et al., 2012). These test statistics were calculated for the entire data set to observe changes across the whole available sample. They were also calculated for each individual project within the study, as sample sizes for individual projects were small exact test statistics were used (Mehta & Patel, 2013). The effect size,  $r$ , was manually calculated for the test of significance using equation 5.1. IBM SPSS Statistics 22 was used to perform all other calculations in this analysis.

### Teacher Data

The analysis of the teacher questionnaire is split into quantitative and qualitative results. Firstly, the quantitative results were presented and non-parametric descriptive statistics of central tendency and variance were calculated. Box plots were used to present the descriptive analysis of the competence statements.

Pearson Correlation calculations were performed to correlate the participant descriptive data collected in Section 1 of the teacher questionnaire with the median scores of teaching confidence from Section 2. This was used to

identify if the factors of teacher experience and knowledge correlate with confidence in teaching scores.

The results of the technology competences self-assessment from Sections 2 and 4 of the teacher questionnaire were compared to assess if there had been any significant changes in teaching confidence as a result of the project. The same Wilcoxon Signed Rank Tests methods were used for the teacher questionnaire as were used for the pupil questionnaire.

Qualitative responses to the questionnaires were analysed using thematic analysis (Braun & Clarke, 2006). Codes were generated from the data analysis and were presented alongside the number of codes from unique participants in Table 6.15, Table 6.16. and Table 6.17.

#### Twilight Sessions and Showcase Lessons

The data collected in on the twilight sessions during Phase 1 and the Showcase lessons in Phase 4 were analysed by other members of the team evaluating the “STEM into Action with D&T” project. The figures of attendance at the twilight session and the number of showcase lessons produced have been included in the results, see section 6.6, with a summary of the findings.

#### Missing Data

There was a total of 82 schools, across both samples, registered to participate in the project. Following repeated reminders and requests to complete and return questionnaires the total number of responses was from 31 schools. This gives a final response rate of 38%. This rate is acceptable for the use of postal questionnaires (Cohen et al., 2007). The possibility of any bias introduced by this responses rate was included in the discussion. The response rates and missing data for the pupil and teacher questionnaires are analysed individually in sections 6.3.1 and 6.4.1.

### **6.3. Results of Pupil Questionnaire**

#### **6.3.1. Participants**

The number of questionnaire responses and the amount of missing data from the responses are shown in Table 6.1. A total of 959 participated in some part of the questionnaire process, from 31 schools.

860 pupils returned the start of project questionnaire, 117 of the start of project questionnaires were rejected due to missing data or errors made on the questionnaire resulting in a total of 743 complete responses.

699 pupils returned the end of project questionnaire, 101 of the end of project questionnaires were rejected due to missing data or errors made on the questionnaire resulting in a total of 598 complete responses.

652 pupils returned both the start and end of project questionnaire, 194 participants results were rejected due to missing data or errors made on the questionnaire resulting in a total of 458 complete responses.

Table 6.1 Number of questionnaire responses and missing data for the pupil questionnaire

	Number of responses	Number of Complete Responses	Missing Data
Start of project pupil questionnaire	860	743	13.60%
End of project pupil Questionnaire	699	598	14.45%
Both the start and end of project pupil questionnaires	652	458	29.75%
Total unique pupils (n = 959), Total unique schools (n = 31)			

With the amount of missing data for participants who completed the before and after questionnaires at 29.75% data imputation methods were considered unsuitable (Gelman & Hill, 2006; Scheffer, 2002). Cases with missing data values have been excluded test-by-test to preserve the maximum amount of useable data. The size of the sample used in each calculation is provided in these results.

The sample size of 458 provides a confidence interval of 4.58% at 95% confidence level. Calculated using Equation 3.1 and a population figure of 483,795 state funded secondary school pupils (Department for Education, 2015c). Therefore, the sample can be considered valid and the data for complete cases has been used.

The total number of unique pupils that participated in the study were 959. The gender distribution shown was 234 males, 419 females and 306 with no answer given. The distribution of gender was skewed towards a high percentage of female pupils responding. Of the 31 responding schools, 3 were all girls and 1 was all boys.

### 6.3.2. Factor Analysis

Two factor analyses were calculated for the 18 items in each of the Start and End of project pupil questionnaires. Initially the factorability of the 18 items in each questionnaire was examined. For the start of project questionnaire, the Kaiser-Meyer-Olkin Measure of sampling Adequacy was 0.922, above the recommended value of 0.6, and Bartlett's test of sphericity was significant ( $\chi^2(153) = 6773.252, p < .01$ ). For the end of project questionnaire, the Kaiser-Meyer-Olkin Measure of sampling Adequacy was 0.932, above the recommended value of 0.6, and Bartlett's test of sphericity was significant ( $\chi^2(153) = 6621.758, p < .01$ ). Given these indicators, factor analysis was conducted on all 18 items in both questionnaires.

EFA was conducted using the maximum likelihood method with oblique rotation using the Oblimin with Kaiser Normalization rotation method. Three factors were extracted for each of the 18 items in the two questionnaires. Values for the start of project pupil questionnaire showed that factor 1 explained 37.9% of the variance, factor 2 explained 8.3% of the variance and factor 3 explained 6.0% of the variance. The 3 factor solution for the start of project questionnaire explained 52.1% of the total variance. Values for the end of project pupil questionnaire showed that factor 1 explained 43.7% of the variance, factor 2 explained 8.9% of the variance and factor 3 explained 4.9% of the variance. The 3 factor solution for the end of project questionnaire explained 57.5% of the total variance.

The loading of factors for the start and end questionnaires are shown in Table 6.2 and Table 6.3 respectively. The items have been organised by their highest factor loading. The highest loading of each item is shown in bold type. The items and factors calculated in this EFA match the intended design of the questionnaire. As planned the loading of items to factors is the same in the start and end questionnaires. Questions 1, 3, 6, 8, 14, 15 and 18 load onto factor 1 Interest/Enjoyment, questions 2, 12, 13, 16 and 17 load onto factor 2 Pressure/Tension and questions 4, 5, 7, 9, 10 and 11 load onto factor 3 Perceived Competence.

The factor pressure/tension would be expected to have an inverse relationship to perceived competence. The structure matrix used has revealed the high levels of expected correlation between factors. This

negative correlation is demonstrated in the significant negative loading on Items 11, 12 and 13. The items are sensitive to order and this could explain lower levels of primary loading for items 11 and 13 compared to previous experiments.

Table 6.2 Structure matrix of factor loadings based on EFA using maximum likelihood and oblimin rotation for 18 items in the start of project pupil questionnaire (n = 743)

	Factor		
	(1) Interest/Enjoyment	(2) Pressure/Tension	(3) Perceived Competence
SQ1	<b>.669</b>	-.380	.338
SQ3	<b>.758</b>		.454
SQ6	<b>.487</b>	-.409	
SQ8	<b>.838</b>		.633
SQ14	<b>.841</b>		.538
SQ15	<b>.884</b>		.582
SQ18	<b>.630</b>		.409
SQ2	-.402	<b>.571</b>	
SQ12		<b>.356</b>	-.418
SQ13	-.480	<b>.547</b>	-.627
SQ16		<b>.803</b>	
SQ17		<b>.801</b>	-.322
SQ4	.435		<b>.783</b>
SQ5	.394		<b>.744</b>
SQ7	.482		<b>.624</b>
SQ9	.551		<b>.707</b>
SQ10	.525		<b>.785</b>
SQ11		-.415	<b>.360</b>

Note: Factor loading < .32 are suppressed



Table 6.3 Structure matrix of factor loadings based on EFA using maximum likelihood and oblimin rotation for 18 items in the end of project pupil questionnaire (n = 597)

	Factor		
	(1) Interest/Enjoyment	(2) Pressure/Tension	(3) Perceived Competence
EQ1	<b>.715</b>	-.359	.424
EQ3	<b>.811</b>		.568
EQ6	<b>.602</b>	-.396	
EQ8	<b>.879</b>		.646
EQ14	<b>.823</b>		.583
EQ15	<b>.862</b>		.545
EQ18	<b>.676</b>		.461
EQ2	-.402	<b>.555</b>	-.388
EQ12		<b>.447</b>	-.473
EQ13	-.502	<b>.562</b>	-.608
EQ16		<b>.809</b>	-.390
EQ17		<b>.842</b>	-.360
EQ4	.533	-.363	<b>.806</b>
EQ5	.442	-.322	<b>.735</b>
EQ7	.580	-.388	<b>.679</b>
EQ9	.601	-.411	<b>.838</b>
EQ10	.601	-.403	<b>.845</b>
EQ11	.375	-.519	<b>.430</b>

Note: Factors loading < .32 are suppressed

### 6.3.3. Validity Test

Internal consistency for each of the factors was examined using Cronbach's alpha. For the start of project pupil questionnaire the Interest/Enjoyment factor consisted of 7 items (n = 785,  $\alpha = .887$ ), the Pressure/Tension factor consisted of 5 items (n = 787,  $\alpha = .773$ ), the Perceived Competence factor consisted of 6 items (n = 827,  $\alpha = .824$ ). For the end of project pupil questionnaire the Interest/Enjoyment factor consisted of 7 items (n = 636,  $\alpha = .905$ ), the Pressure/Tension factor consisted of 5 items (n = 648,  $\alpha = .800$ ), the Perceived Competence factor consisted of 6 items (n = 652,  $\alpha = .865$ ). All calculated alphas were above the recommended 0.7 threshold for acceptance.

### 6.3.4. Descriptive Statistics

For each pupils complete questionnaire the 3 factor scores were calculated. Central tendency statistics were calculated for the three factors in the start and end of project questionnaires, these are presented in Table 6.4.

Table 6.4 Central tendency statistics for pupil questionnaire factor scores

	Start (n = 743)		End (n = 598)	
	Median	IQR	Median	IQR
Interest/Enjoyment	4.9	1.5	4.9	1.5
Perceived Competence	4.7	1.0	4.8	1.2
Pressure/Tension	3.2	1.6	3.0	1.3

The calculated scores for all the factors are presented as box plots for descriptive analysis, see Figure 6.2. There were more responses to the start of project questionnaire (n = 743) compared to the end of project questionnaire (n = 598). The score is based on a 7 point Likert scale, scores greater than 4 are positive responses from pupils; scores less than 4 are negative responses.

The central tendency statistics and box plot show the high starting position for Interest/Enjoyment and Perceived Competence and the low starting position of Pressure/Tension. Higher scores are desirable for Interest/Enjoyment and Perceived Competence, while low scores are desirable for Pressure/Tension.

The results in Table 6.4 and Figure 6.2 show no change in the median scores for Interest/Enjoyment between the start and end of the project. There is an increase in median Perceived Competence scores between start and end of the project and a decrease in median Pressure/Tension scores. These changes have been tested for significance in section 6.3.5.

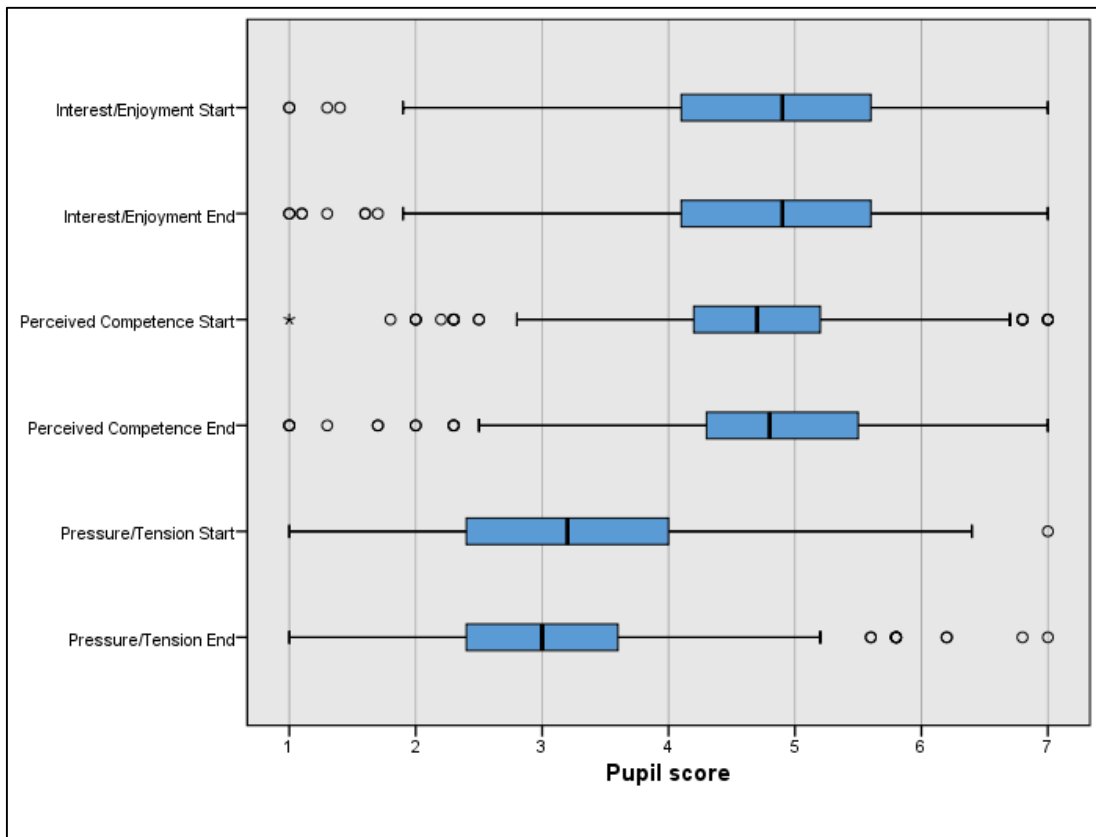


Figure 6.2 Box plots of calculated pupil IMI scores comparing all pupil scores on before and after questionnaires  
 Note. Outliers are identified as: o = outliers. \* = extreme values

Central tendency statistics were also calculated for the starting scores for male and female participants, Figure 6.3. The figure shows that female participants responded with lower median factors scores in Interest/Enjoyment and in Perceived Competence than the male pupils. The female participants also scored higher in Pressure/Tension than the male pupils. The female pupils have score themselves as being less motivated and less able in technology education, but they are also less pressured than the male pupils.

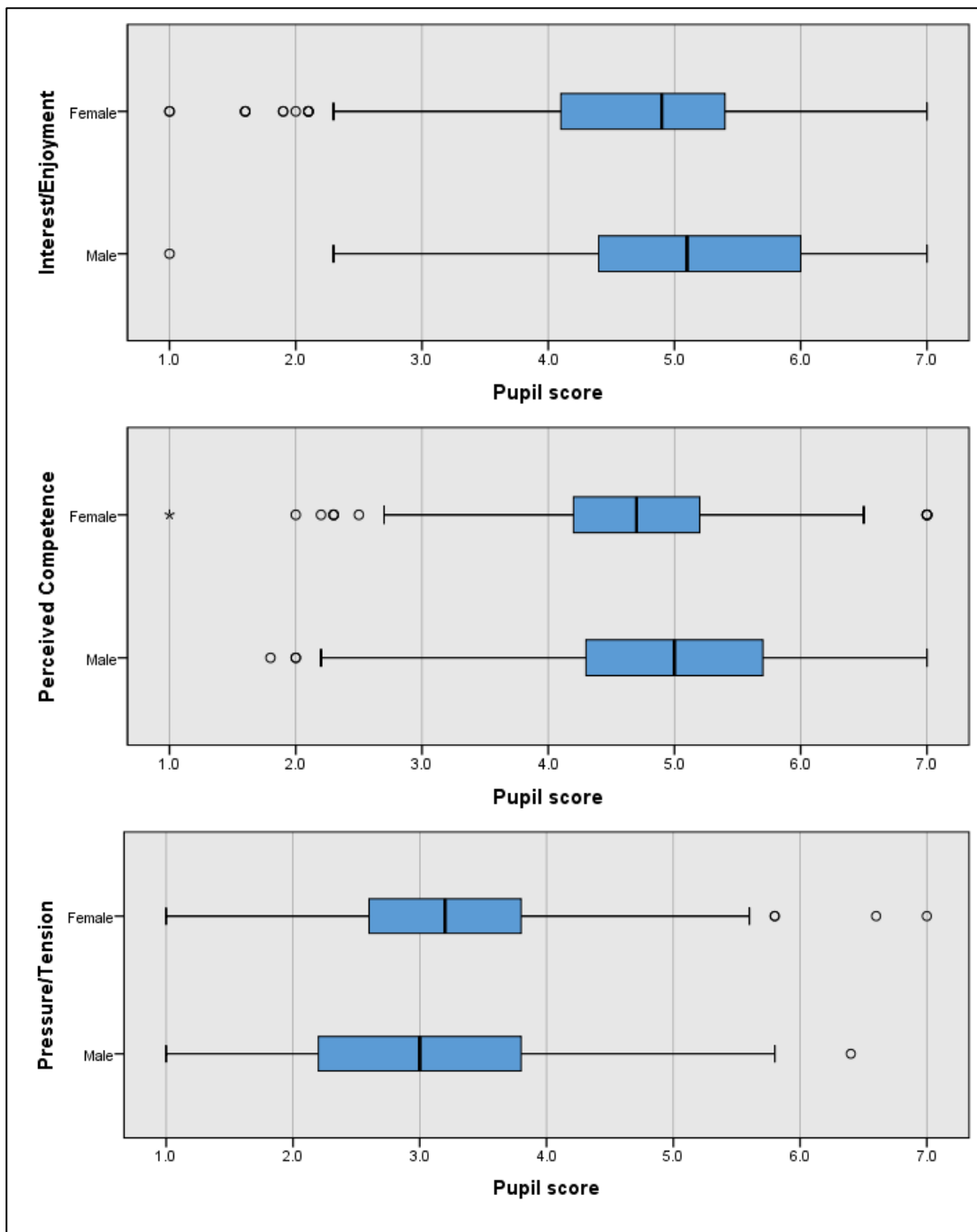


Figure 6.3 Pupil factor scores for the start of project questionnaire split by gender

### 6.3.5. Changes to pupil scores

The first calculated differences in pupils scores between the start and end of the project were made on all available data to report impact for the entire study.

No significant difference between start ( $n = 743$ ,  $Mdn = 4.9$ ,  $IQR = 1.5$ ) and end ( $n = 598$ ,  $Mdn = 4.9$ ,  $IQR = 1.5$ ) of project Interest/Enjoyment scores was found using a Wilcoxon Signed Ranks Test of Asymp. Sig. (2-tailed) ( $n = 458$ ,  $Z = -1.427$ ,  $p = .154$ ,  $r = 0.05$ ). There was no significant change in the

whole study scores of pupil Interest/Enjoyment. However, the median starting score was that pupils were already positively motivated in technology.

A significant difference between start (n = 743, Mdn = 4.7, IQR = 1.0) and end (n = 598, Mdn = 4.8, IQR = 1.2) of project Perceived Competence scores was found using a Wilcoxon Signed Ranks Test of Asymp. Sig. (2-tailed) (n = 458, Z = -3.994,  $p < .001$ ,  $r = 0.13$ ). There was a significant increase in the whole study scores of pupil Perceived Competence.

A significant difference between start (n = 743, Mdn = 3.2, IQR = 1.6) and end (n = 598, Mdn = 4.8, IQR = 1.3) of project Pressure/Tension scores was found using a Wilcoxon Signed Ranks Test of Asymp. Sig. (2-tailed) (n = 458, Z = -4.278,  $p < .001$ ,  $r = 0.14$ ). There was a significant decrease in the whole study scores of pupil Pressure/Tension.

The calculations of factor scores for each gender are presented in Table 6.5. There was no significant difference between the aggregate factors scores and the factor scores of male and female pupils.

Table 6.5 Gender differences for pupil questionnaire scores

Factor	Male (n = 116)			Female (n = 232)		
	Z	p	r	Z	p	r
Interest/Enjoyment	-0.225	.822	0.01	-1.297	.195	0.06
Perceived Competence	-2.332*	.020	0.15	-2.807**	.005	0.13
Pressure/Tension	-2.687**	.007	0.18	-3.925***	.000	0.18

Significant at \* $p < .05$ , two-tailed. \*\* $p < .01$ , two-tailed. \*\*\* $p < .001$ , two-tailed.

The size effect of the statistical calculations above were small ( $r < .3$ ) and required further analysis. This was achieved through the calculation of Wilcoxon Signed Ranks Test statistics for each individual school. This identified changes to the factor scores in more detail and described the impact of the project in each school. Exact significance tests were calculated as the sample size from individual schools is small. The calculations for each school's pupil change in factor scores are shown in Table 6.6. The statistically significant results are marked with the direction of change. In 5 schools, 0 pupils returned both the start and end of project questionnaires, and therefore no change in project score statistics could be calculated for these schools.

This more detailed analysis shows that actually only 6 of the 31 schools had a statistically significantly positive improvement in pupil Interest/Enjoyment, see the items marked *a* in Table 6.6 for Schools 2, 5, 10, 20, 25 and 26. The factors of Interest/Enjoyment and Perceived Competence that have statistically significant changes feature mostly positive improvements and the Pressure/Tension factor are mostly negative, as would be expected from a successful intervention in schools.

The unexpected significant results are with schools 4, 14 and 27. These schools have inverse significant changes which would suggest reductions in pupil of Interest/Enjoyment and Perceived Competence and increases in Pressure/Tension as a result of the intervention.

Table 6.6 Changes in pupil scores between start and end of project for each individual school

Wilcoxon Signed Rank Test, $Z(p)$				
Unique School ID	n	Interest/Enjoyment	Perceived Competence	Pressure/Tension
1	13	-1.494(.073)	-1.833(.033) <sup>a</sup>	-2.814(.001) <sup>b</sup>
2	26	-2.152(.015) <sup>a</sup>	-2.021(.021) <sup>a</sup>	-1.232(.113)
3	25	-.822(.211)	-.229(.414)	-.35(.368)
4	27	-3.52(0) <sup>b</sup>	-2.605(.004) <sup>b</sup>	-.217(.418)
5	20	-1.942(.026) <sup>a</sup>	-1.972(.024) <sup>a</sup>	-2.325(.009) <sup>b</sup>
6	0	.	.	.
7	12	-.846(.215)	-.788(.231)	0(.504)
8	22	-.212(.421)	-.486(.32)	-1.294(.104)
9	15	-.659(.266)	-.699(.255)	-.655(.266)
10	22	-1.795(.037) <sup>a</sup>	-2.071(.019) <sup>a</sup>	-.263(.401)
11	16	-.655(.266)	-1.396(.086)	-.211(.427)
12	19	-.085(.472)	-2.696(.002) <sup>a</sup>	-2.262(.011) <sup>b</sup>
13	0	.	.	.
14	21	-1.113(.138)	-2.391(.007) <sup>b</sup>	-3.042(.001) <sup>a</sup>
15	10	-1.262(.117)	-.423(.367)	-1.428(.084)
16	25	-.341(.372)	-.564(.292)	-2.268(.011) <sup>b</sup>
17	0	.	.	.
18	18	-1.156(.134)	-.442(.344)	-.315(.386)
19	0	.	.	.
20	16	-2.182(.013) <sup>a</sup>	-3.063(0) <sup>a</sup>	-2.609(.004) <sup>b</sup>
21	0	.	.	.
22	26	-1.341(.093)	-1.003(.163)	-.259(.404)
23	14	-.847(.211)	-1.336(.098)	-2.003(.024) <sup>b</sup>
24	13	-1.016(.166)	-2.536(.004) <sup>a</sup>	-1.191(.126)
25	35	-3.932(0) <sup>a</sup>	-3.325(0) <sup>a</sup>	-2.318(.01) <sup>b</sup>
26	5	-2.032(.031) <sup>a</sup>	-2.032(.031) <sup>a</sup>	-2.023(.031) <sup>b</sup>
27	11	-1.188(.133)	-2.001(.022) <sup>b</sup>	-1.995(.025) <sup>b</sup>
28	3	-1(.5)	0(.625)	-1.633(.125)
29	21	-1.322(.097)	-1.291(.105)	-.142(.45)
30	8	-.734(.281)	-1.859(.039) <sup>a</sup>	-.773(.258)
31	15	-.874(.202)	-.595(.303)	-1.28(.122)

<sup>a</sup> Significant positive change in scores ( $p < .05$ , Exact Sig. 1-tailed)

<sup>b</sup> Significant negative change in scores ( $p < .05$ , Exact Sig. 1-tailed)

## 6.4. Quantitative Results of Teacher Questionnaire

### 6.4.1. Participants

There were 33 responses to the teacher questionnaires from 31 schools.

Two teachers responded from School 7 and School 13. The number of questionnaire responses and the amount of missing data from the responses are shown in Table 6.7

22 teachers returned the start of project questionnaire, 3 of the start of project questionnaires were rejected due to missing data or errors made on the questionnaire resulting in a total of 19 complete responses.

30 teachers returned the end of project questionnaire, 6 of the end of project questionnaires were rejected due to missing data or errors made on the questionnaire resulting in a total of 24 complete responses.

18 teachers returned both the start and end of project questionnaire, 3 participants results were rejected due to missing data or errors made on the questionnaire resulting in a total of 15 complete responses.

Table 6.7 Number of questionnaire responses and missing data for the teacher questionnaire

	Number of responses	Number of Complete Responses	Missing Data
Start of project teacher questionnaire	22	19	13.64%
End of project teacher Questionnaire	30	24	20.00%
Both the start and end of project teacher questionnaires	18	15	54.55%
Total unique teachers (n = 33)			

The data are not suitable for imputation due to the small sample size.

Multiple imputation methods are used on studies with samples greater than 100 (Yoo, 2009). Cases with missing data values have been excluded test-by-test to preserve the maximum amount of useable data. The size of the sample used in each calculation is provided.

The sample comprised 39% males (n = 13) and 48% females (n = 16), 12% missing data (n = 4).

The first degrees of participants are shown in Table 6.8. The majority of participants' first degrees were in a creative arts and design subject (n = 16). The frequencies of the type of degree are shown in Table 6.9.

The most common route for ITT was a 1 year PGCE course (n = 18). In descending order, the other routes followed for ITT were 2 year PGCE (n = 4), Undergraduate (n = 3), Teach First (n = 3), other (n = 1) and 4 participants with no response.

The reported levels of teaching experience were high, with 20 participants having more than 5 years teaching experience, see Table 6.10. The levels of



experience were reflected in the seniority of the participants, with 16 participants in a position of responsibility within their subject or department, see Table 6.11.

Table 6.8 First degrees of participants by JACS group

First Degree	Frequency
Architecture, building & planning	2
Business & administrative studies	1
Creative arts & design	16
Engineering & technology	2
Missing Data	12

Table 6.9 Type of first degree held by participants

Degree Type	Frequency
BA	21
BSc	4
BEng	2
Other	2
Missing Data	4

Table 6.10 Teaching experience of participants

Number of years teaching experience	Frequency
Less than 1	1
1 to 5	8
6 to 10	10
More than 10	10
Missing Data	4

Table 6.11 Participants' positions of responsibility

Position of responsibility	Frequency
Teacher	11
Subject Leader	10
Head of Faculty	6
Other	2
Missing Data	4

The amount of technology training undertaken by the sample was varied, with 8 participants undertaking no technology training, this was assessed by the number of half-days spent on technology CPD in a typical school year ( $n = 33$ ,  $M = 2.39$  95% CI[1.39,3.40],  $SD = 2.84$ ).

### 6.4.2. Descriptive Statistics

Teachers were asked to rate their confidence of 25 items on a 7 point Likert scale at the start and end of the projects.

Central tendency and variance statistics were calculated to explore the responses to the individual teaching confidence items on the start of project questionnaire. The median, IQR and range statistics are presented as box plots in Figure 6.4. The box plot shows that the data is skewed towards high scoring responses. However, some items can be identified as weaknesses by their low or neutral median scores Q4, Q7, Q8, Q13, Q14, Q15 and Q22. The other 18 items have positive confidence median scores. Items Q1, Q9, Q16, Q17, Q19, Q23 and Q24 have all scored very highly with positive scores across their entire range.

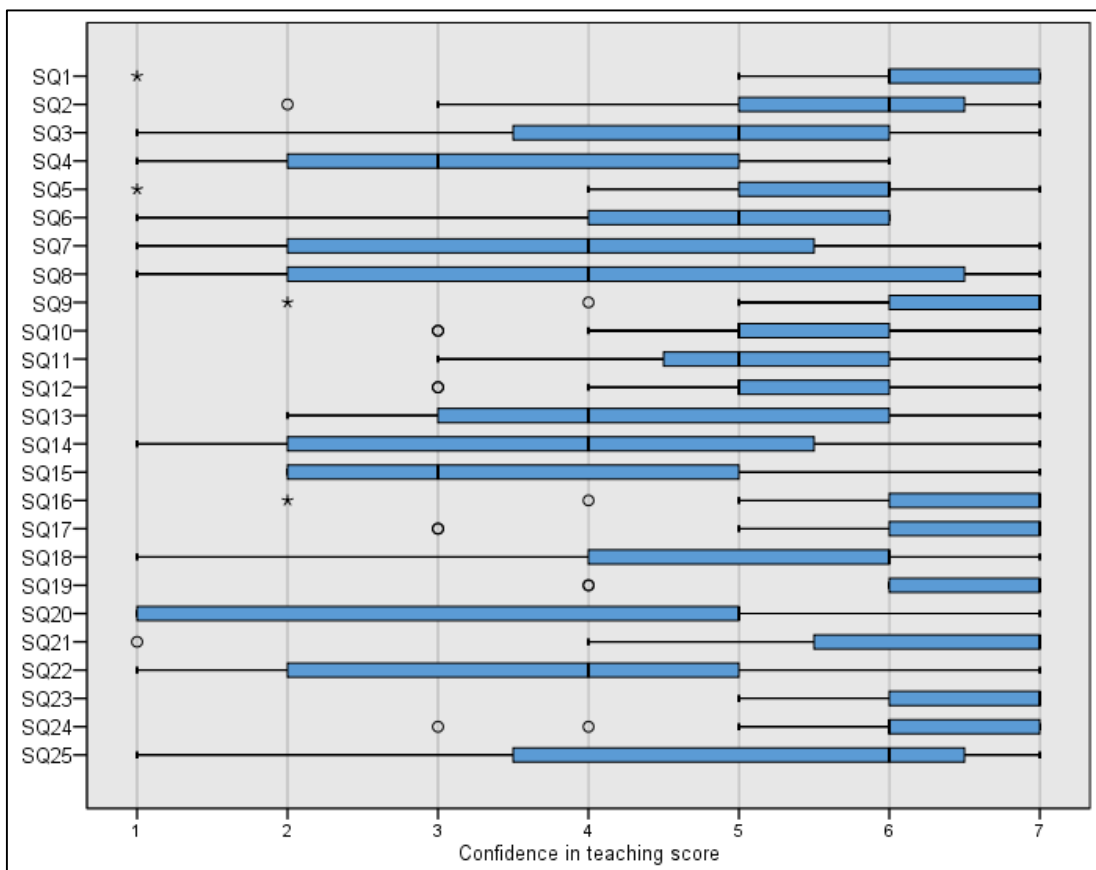


Figure 6.4 Box plots of questionnaire item totals for teacher start of project questionnaire  
 Note. Outliers are identified as: o = outliers. \* = extreme values

Central tendency and variance statistics were calculated to explore the responses of each individual teacher's technology confidence on the start of project questionnaire for all 25 items on the start of project questionnaire. These statistics for the 19 teachers who completed the start of questionnaire

are presented as box plots in Figure 6.5. The values for the percentage of items taught by each teacher are also presented, where available, in brackets next the label of each teacher in Figure 6.5.

The data are highly skewed towards positive scores for teaching confidence, 16 out of 19 teachers with a positive median score. There was only a single teacher with a negative median confidence score and 2 neutral scores. Nine teachers appear to have a lot of variance in their teaching confidence across all the items rated, express by a IQR  $\geq 3$ .

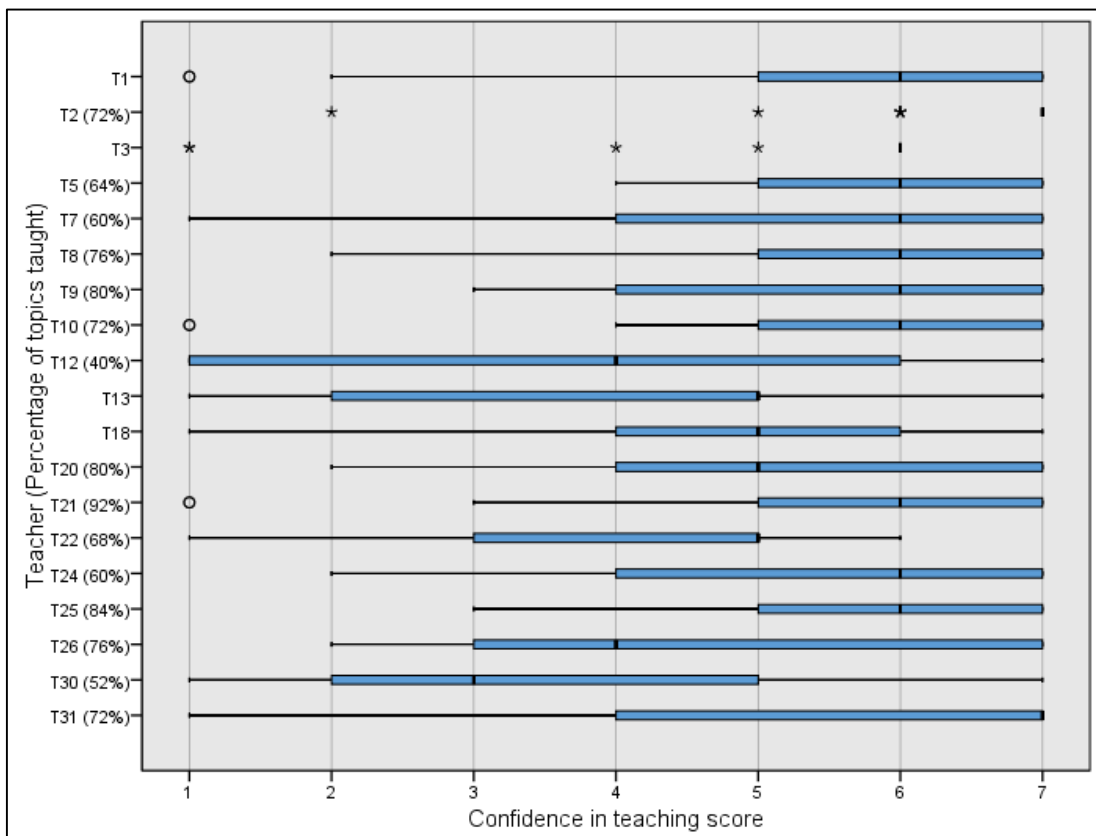


Figure 6.5 Box plots of teacher totals for teacher start of project questionnaire  
Note. Outliers are identified as: o = outliers. \* = extreme values

The average percentage of the number of items that have been actually taught by teachers was high ( $n = 15$ ,  $M = 69.87$  95% CI[62.75, 77.16],  $SD = 13.17$ ).

A Pearson product-moment correlation coefficient was calculated to assess the relationship between the start of project confidence score and each of the participant information variables, Table 6.12.

Table 6.12 Correlation of participant descriptive data and start of project confidence score

	Start of project confidence score	
	Pearson Correlation	Sig. (2-tailed)
Gender	-.229	.430
Degree group	.194	.506
Degree type	.350	.220
ITT Route	-.426	.129
Years of Experience	.551*	.041
Position of responsibility	.099	.735
Technology CPD training	-.481	.082
Percent of questionnaire items taught	.608*	.021

\*. Correlation is significant at the 0.05 level (2-tailed).  
(n = 14)

Two significant correlations were calculated in Table 6.12. The first correlation was between the start of project teaching confidence score and the number of years of teaching experience ( $n = 14$ ,  $r = .551$ ,  $p = 0.041$ ). The second correlation was between the start of project teaching confidence score and the percentage of questionnaire items taught ( $n = 14$ ,  $r = .608$ ,  $p = .021$ ). The more experienced teachers had taught more topics and rated themselves as more confident in teaching. There was no significant correlation between the other 6 items and the confidence teaching score.

Teachers were requested to assess their collaboration with science and mathematics teachers on STEM projects, in the start of project questionnaire. Teachers were requested to rate their agreement with the statement “It may be argued that in order to provide the best educational experience to pupils D&T teachers should collaborate with colleagues from different disciplines in the application of STEM within D&T projects” on a 7 point Likert Scale (1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree). The result was teachers agreement to the statement ( $n = 32$ , Mdn = 6, IQR = 2).

Teachers were then requested to state if they had collaborated with other disciplines. Thirteen teachers had collaborated with a colleague in maths and 21 with a colleague in science on a D&T project, out of a total of 32 responses with 1 teacher not responding.

The end of project questionnaire asked teachers to assess their preferred methods of CPD delivery. Five different options were presented and respondents ( $n = 27$ ) could choose any that were right for them. The counted responses were sorted in descending order. Demonstrations and discussions

from other teachers (n = 26), short course (n = 23), video and paper guides (n = 18), accredited course with recognised qualification (n = 18) and online guides (n = 15).

#### **6.4.3. Changes to teacher scores**

To assess if there were any significant differences to confidence in technology teaching between the start and end of the study Wilcoxon Signed Ranks Tests were calculated.

A significant difference in start (n = 19, Mdn = 5.4, IQR = 1) and end (n = 24, Mdn = 5.6, IQR = 1) of project scores for all teachers was found using a Wilcoxon Signed Ranks Test of Exact Significance (2-tailed) (n = 15, Z = -3.150,  $p = .001$ ,  $r = .58$ ). There was a significant increase in the scores of teacher confidence in technology teaching.

The differences for each individual item on the questionnaire were also calculated using a Wilcoxon Signed Ranks tests for increases in the scores. The test statistics calculated in Table 6.13 revealed that there were significant improvements in teaching confidence scores for 3 items of the questionnaire. These were Q13, how to produce products that contain electronic sensors and outputs; Q14, programming and Q15, incorporating microcontrollers into their products. The remaining 22 items had no significant improvement.

Table 6.13 Changes in teacher scores between start and end of project for each individual item

Questionnaire Item	Wilcoxon Signed Ranks test		
	Z	p	r
EQ1 > SQ1	0	1.000	.00
EQ2 > SQ2	-2	.063	.37
EQ3 > SQ3	-1.732	.125	.32
EQ4 > SQ4	-1.414	.156	.26
EQ5 > SQ5	-1	.500	.18
EQ6 > SQ6	-0.707	.375	.13
EQ7 > SQ7	-1	.313	.18
EQ8 > SQ8	-0.447	.500	.08
EQ9 > SQ9	-1	.500	.18
EQ10 > SQ10	-1	.500	.18
EQ11 > SQ11	-1.732	.125	.32
EQ12 > SQ12	0	.688	.00
EQ13 > SQ13	-2.121*	.031	.39
EQ14 > SQ14	-2.232*	.016	.41
EQ15 > SQ15	-2.251*	.016	.41
EQ16 > SQ16	0	.750	.00
EQ17 > SQ17	-1	.500	.18
EQ18 > SQ18	-1.633	.125	.30
EQ19 > SQ19	0	.750	.00
EQ20 > SQ20	-0.816	.375	.15
EQ21 > SQ21	-1	.500	.18
EQ22 > SQ22	-0.816	.375	.15
EQ23 > SQ23	0	1.000	.00
EQ24 > SQ24	-1	.500	.18
EQ25 > SQ25	-0.447	.500	.08

\*  $p < .05$  Exact Sig 1-tailed

Note: EQ = End Question, SQ = Start Question

The differences in teaching confidence score for each individual teacher who completed both the start and end of project questionnaires were calculated using a Wilcoxon Signed Ranks tests for increases in the scores. The test statistics calculated in Table 6.14 revealed that there were significant improvements in teaching confidence scores for 4 teachers. The majority of teachers who completed both the start and end of project teaching confidence questionnaire did not have any significant change ( $n = 11$ ).

Table 6.14 Changes in teacher scores between start and end of project for each individual teacher

Teacher	Wilcoxon Signed Ranks test		
	Z	<i>p</i>	<i>r</i>
T1	-1.000	.317	.20
T2	-1.732	.083	.35
T3	-.816	.414	.16
T5	-2.000*	.046	.40
T7	.000	1.000	.00
T8	-1.000	.317	.20
T10	-1.841	.066	.37
T13	-2.041*	.041	.41
T18	-2.476*	.013	.50
T20	-.184	.854	.04
T22	-.577	.564	.12
T24	-2.484*	.013	.50
T25	-1.000	.317	.20
T26	-1.342	.180	.27
T31	-1.000	.317	.20

\* *p* < .05 2-tailed.

## 6.5. Qualitative Results of Teacher Questionnaire

The final section of the end of project questionnaire asked for teachers' positive and negative feedback to any aspects of the project. These responses were transcribed verbatim from the paper questionnaires, then analysed and coded.

Initially the transcribed responses were read and potential themes for analysis were coded. Key themes related to the research questions were extracted. The themes were refined through a second reading of the whole text and of the coded extracts already identified. The final themes and coded items are presented. Prevalence of themes are represented by uniquely coded extracts representing the number of individual teachers who were coded for each theme (Braun & Clarke, 2006).

Quotes from the teachers are labelled with T followed by the number of the teacher for the study.

### 6.5.1. Positive Feedback

Responses to the question "What was the best thing about the project?" were coded into 6 categories, producing 44 coded responses by 27 unique

participants; the categories and number of coded responses are shown in Table 6.15.

Table 6.15 Codes used to analyse teacher positive feedback

Code	Number of coded responses from unique participants
Developing new schemes of work	14
Developing pupils capability	11
Pupil interest	7
Discussing work with other teachers	7
Professional Support	4
Awareness of subject	1

### Developing new schemes of work

The most frequently coded response was about the projects ability to enable teachers to develop new schemes of work; this was stated by 14 different participants. Participants stated that the resources enabled them to develop new projects; this was a positive impact to the participants. The following statements suggest that the resources enabled the development of new projects within the schools that expanded existing teaching methods:

T11, a STEM coordinator with more than 10 years of experience:

*“Chance to experiment and change the normal design/make agenda with the pupils.”*

T13, a head of faculty with 6 to 10 years of experience:

*“Being able to trial different resources with different groups and not being afraid to take risk.”*

T19, a subject leader with more than 10 years of experience:

*“Imaginative resources to refresh familiar areas.”*

T2, a teacher with 6 to 10 years of experience commented on the specific resources that were used to develop new projects:

*“Integrating smart materials into projects. Using LED and other electronic based projects.”*

T31, a teacher with 6 to 10 years of experience reported that the project enabled the school to have new resources however; the comment exposed



the problem of the sustainability of the project due to the cost of restocking resources:

*“Being able to try out new technology which our dept [department] would have been unable to afford otherwise.”*

#### Developing pupils’ capability

Eleven participants reported that the project enhanced pupil learning and capability. Participants reported that the pupils benefitted from the context that the resources provided for teaching technology.

T2, a teacher with 6 to 10 years of experience explained that the pupils were able relate to the context of the resources:

*“[...] relevant and useful for students. They can relate to it a lot more”*

T13, a head of faculty with 6 to 10 years of experience use the resources to provide links outside the classroom:

*“Linking outcomes to industry eg. Injection moulding.”*

T11, a STEM Coordinator with more than 10 years of experience:

*“Design with models and experiment with final pieces”*

The participants also reported that the resources benefitted pupils by providing links to STEM. The National Curriculum states that pupils should draw on their knowledge of maths and science.

T9, a subject leader with 1 to 5 years of experience reported including applied science into the project:

*“The students were able to learn about relevant technology and understand a lot more applied science in practicality”*

T24, a teacher with 1 to 5 years of experience reported including maths and science into the project:

*“Applying more maths and science knowledge to their practical projects. Linking D&T, maths and science into one project”*

Two participants reported that the length of the project was beneficial to the pupils. The resource can provide shorter learning tasks that are quicker to

introduce, than traditional extended design and make activities, and provide achievable goals for pupils.

T20, a subject leader with 6 to 10 years of experience reported that pupils could complete the resources:

*“Easy to achieve outcomes for student led activity”*

T25, a teacher with 6 to 10 years of experience reported that the resources provided short tasks for pupils:

*“having more options to introduce very quick engaging projects which helped students develop their thinking skills.”*

Two participants reported that the resources extended the learning objectives beyond existing work. This is beneficial to pupils if it can be sustained beyond the funding this project provided.

T8, a teacher with 1 to 5 years of experience:

*“Allowing students time and opportunities to problem solve and experiment with the structure of their prototype. Students able to create art work that they would otherwise not be able to produce”*

T33, a head of faculty with 6 to 10 years of experience:

*“Using new resources which challenged the type of content that we chose to deliver as a school – more experimental.”*

Participants reported that pupils find electronics difficult. However, the resources helped participants to deliver the content to pupils in a more accessible way and to a wider group of pupils. The resources have developed a new starting point for teaching electronics for these participants.

T14, a subject leader with 6 to 10 years of experience :

*“Simple way to introduce electronics as many students find this area difficult to grasp”*

T15, a subject leader with more than 10 years of experience:

*“some y9 girls struggled with the electronic project, so I will introduce a simpler one in y8 and build on this”*

### Pupil interest

Comments about the amount of interest pupil's had in the project were made by 7 teachers. From the comments it can be seen that from the teachers' perspective, pupils were very enthusiastic about the projects. The use of materials resources was frequently reported. Examples of comments were made by:

T3, a subject leader with more than 10 years of experience stated that his pupils were enthusiastic; this was attributed, by the participant, to the experimental tutorial resources:

*"Pupils enthusiasm. The worksheets used, did excite pupils. Particularly the SMA worksheet"*

T5, a head of faculty with 1 to 5 years of experience reported the beneficial effect of the SMART materials resources as they provide visual feedback of their properties to pupils:

*"Students really engage with the visual side of the materials. All particularly enjoyed the thermochromic & shape memory alloys"*

T6, a teacher with more than 10 years of experience:

*"Seeing the reaction of the students as they learn about electronics"*

T15, a subject leader with more than 10 years of experience:

*"To see pupils reaction to the smart materials. They loved the photochromic and encapsulated paints"*

T18, a subject leader with 1 to 5 years of experience reported the enthusiasm pupils had to the new resources:

*"they [the resources] had a great 'wow' factor. The students who did the extension were 'rewarded' with gold [another material to experiment with], which motivated all the other students."*

T20, a subject leader with 6 to 10 years of experience:

*"Quick projects with a lots of students engagement"*

One of the examples contained direct feedback on pupils' engagement with the resources. T26, a head of faculty with 1 to 5 years of experience:

*“The students really enjoyed the Kaleidoscope and the practical tasks in the project. Allowing them to use their phone for kaleidoscope selfies was a “bonus” they said.”*

#### Discussing work with other teachers

The main point of contact for teachers to learn about the resources available was the twilight sessions. There were 6 comments made by teachers that were coded as referring to the usefulness of the twilight sessions. Comments were made by:

T1, a head of faculty with 6 to 10 years of experience:

*“meeting other D&T colleagues to discuss projects at the twilight sessions”*

T4, a STEM Coordinator with 6 to 10 years of experience:

*“Creating links/networking with other schools”*

T19, a subject leader with more than 10 years of experience:

*“Networking with other schools”*

T22, a teacher with 1 to 5 years of experience:

*“The opportunity to meet other enthusiastic teachers and being able to collaborate with them.”*

T32, a subject leader with more than 10 years of experience:

*“Getting out to meet other teachers who share their ideas and experience and having set goals to complete thing by.”*

T33, a head of faculty with 6 to 10 years of experience:

*“I really enjoyed hosting schools at our school so ideas could be shaped.”*

T29, a subject leader with 6 to 10 years of experience commented that it was both the peer-to-peer support of the twilight sessions and the resources provided by other teachers that would have enable them to develop their schemes of work:

*“Accompanying worksheets/teacher advice”*

These comments all suggest that teacher benefit from discussion with other teachers to develop their schemes of work and that teachers perceive it as a useful form of CPD. In these sessions teachers share ideas and their own created resources.

### Professional Support

Teachers also commented on the professional support they received to aid them in delivering the project. This refers to the direct support and resources given to the schools by the D&T Association and the project officers made available to assist schools directly. These comments about support activities have been coded separately from the comments about support given at twilight sessions.

Two participants commented on the support given by individuals and they appear to appreciate having one-to-one support from the project officers. This can be described as expert help or guidance on developing new schemes of work:

T30, a teacher with Less than 1 years of experience:

*“The human support was amazing, generous, enthusiastic, knowledgeable and reliable.”*

T33, a head of faculty with 6 to 10 years of experience:

*“Working with [the project officer] – [their] help/support was really useful” (This comment has been edited to protect the identity of the project officer)*

### Awareness of subject

One comment was coded as awareness of subject. Although it was only made by one participant and there is no further supporting evidence the comment is interesting. The comment was made by T19, a subject leader with more than 10 years of experience:

*“Raised profile of DT in school. SLT [Senior Leadership team] loved the project”*

### **6.5.2. Negative Feedback**

Responses to the question “What was the worst thing about the project?” were coded into 7 categories, producing 31 coded responses by 24 unique

participants; the categories and number of coded responses are shown in Table 6.16.

Table 6.16 Codes used to analyse teacher negative feedback

Code	Number of coded responses from unique participants
Time Constraints	10
Difficulties with projects	6
Cost prohibitive	5
Teacher development	5
Engaging pupils	2
Content of projects	2
Unsustainable in school	1

### Time Constraints

The most frequently coded negative comment was about the time constraints placed on teachers. This was cited by teachers as the reason for negative performance in delivering the projects. Examples of how time constraints had a negative impact on the project were given by:

T2, a teacher with 6 to 10 years of experience:

*“Time limit! – These projects should be run in may/june/july when KS4+5 are away on study leave and there is more time to work with KS3”*

T6, a teacher with more than 10 years of experience:

*“Rushing it due to time constraints”*

T7, a head of faculty with more than 10 years of experience:

*“fitting it in with other work needed”*

T19, a subject leader with more than 10 years of experience:

*“Lack of time to focus on the project. Starting late made things rushed in terms of meetings occurring to close together and not enough thinking time”*

T20, a subject leader with 6 to 10 years of experience:

*“Limited time available.”*

T23, a teacher with more than 10 years of experience:

*“Lack of planning and preparation time prior to starting to use the resources”*

T24, a teacher with 1 to 5 years of experience:

*“We were very time constrained in the project, therefore the quality of the finishing of the final project was not as good as it could be.”*

T25, a teacher with 6 to 10 years of experience:

*“I found it hard sometimes to find time to incorporate some of the resources into lessons for the relevant AS [assessment schemes].”*

T26, a head of faculty with 1 to 5 years of experience:

*“Because of the carousel, time frame are tight and that’s why I only managed to fit in one of the Mindset resource. With my D&T club after school, I will hopefully be able to trial some more specifically the crumble.”*

T32, a subject leader with more than 10 years of experience:

*“Time!”*

The repeated issue of time constraints has appeared to affect teaches in different possible ways:

- The teachers appear to have limited extra time beyond the work they already do and are therefore unable to develop new schemes of work.
- The project timescale was too short for the amount of work required by the participants.
- The time of the year in which the project ran was unsuitable as the pressure of examinations of the older pupils in a school affect the teachers’ ability to test content with their KS3 pupils.

#### Difficulties with projects

Six teachers commented on having difficulties in implementing the projects. These identify problems that will occur when using a kit of parts to deliver a project.

Two participants reported problems with the quality control of the resources available in the project:

T2, a teacher with 6 to 10 years of experience:

*“Not having all the working pieces (mindsets) Bracelets=clips do not work properly.”*

T11, a STEM Coordinator with more than 10 years of experience:

*“Having to make extra components to make the projects work.”*

T13, a head of faculty with 6 to 10 years of experience commented on the limitations of some of the small projects:

*“Limited outcome eg. Picture frame”*

### Cost prohibitive

Cost of the resources was a concern coded in the responses of 5 teachers:

Examples of this were given by:

T4, a STEM Coordinator with 6 to 10 years of experience:

*“You don’t get much for your money after having to purchase the e pack and crumbles would have liked to experiment with more materials.”*

T14, a subject leader with 6 to 10 years of experience:

*“Not being able to use the aluminium rod as is aesthetically pleasing but too expensive.”*

### Teacher development

Five teachers responded that they did not benefit from any professional development during the project and this made it difficult to deliver the projects. Comments made by:

T9, a subject leader with 1 to 5 years of experience:

*“I didn’t necessarily develop and skills as a teacher.”*

T22, a teacher with 1 to 5 years of experience”

*“Being so far away from the twilights and other schools”*

T29, a subject leader with 6 to 10 years of experience:

*“The initial teacher meeting was disjointed, rather disorganised and did not inspire me to either buy into the project or know what*



*best to do to get started. Too much info at once, not enough clarity.”*

T30, a teacher with Less than 1 years of experience:

*“Meetings were very far. More central meetings would have been easier. I would have liked to attend more meetings.”*

T31, a teacher with 6 to 10 years of experience:

*“Having not taught electronics before, I felt at a loss how to use the resources. Step by step plans for basic projects would have been extremely useful.”*

These comments demonstrate dissatisfaction with the peer-to-peer twilight session method of CPD.

### Engaging pupils

Two teachers commented on the difficulty to engage pupils with the technological resources available. The comments were made by:

T5, a head of faculty with 1 to 5 years of experience commented on the problems of engaging specific age ranges:

*“[...] it’s difficult to engage those who have no interest in technology eg. In year 9”*

T20, a subject leader with 6 to 10 years of experience:

*“Students asking to use workshop machinery and make things out of wood!”*

### Content of projects

Two teachers commented that the content of the resources given was not suitable. One teacher requesting further support material, another concerned that the resources did not fit the exam board specifications. Comments were made by:

T18, a subject leader with 1 to 5 years of experience:

*“Lack of classroom resource leading to evidence in books. I’ve attached some that I made, but we could have delivered more, faster, if the theory was more structured from the outset”*

T20, a subject leader with 6 to 10 years of experience:

*“Students still need to be able to use hand skills to satisfy exam board requirements.”*

### Unsustainable in school

One teacher directly stated unsustainability of the resources in schools; T4, a STEM Coordinator with 6 to 10 years of experience:

*“Project developed are unsustainable”*

The other negative feedback comments given could also be described as reasons for unsustainability.

### **6.5.3. Follow Up Question**

Responses to the question “What are the difficulties you face in delivering the D&T curriculum you want to teach?” were coded into 5 categories, producing 13 coded responses by 5 unique participants; the categories and number of coded responses are shown in Table 6.17. The coded responses in this section reflect the participants’ concerns with developing their D&T curriculum beyond the extent of the “STEM into Action with D&T” project.

Table 6.17 Codes used to analyse teacher follow up feedback

Code	Number of coded responses from unique participants
Time to create projects	3
D&T Subject Knowledge	3
School and Curriculum Knowledge	3
Pupils	3
Equipment	1

### Time to create projects

Three participants commented that time was an issue.

Two of these participants reported an awareness for wanting to improve the curriculum and develop new projects but that they are unable to. T11, a STEM Coordinator with more than 10 years of experience reports that CPD would allow them to improve their ability to develop projects, however they feel there is not enough time:

*“The biggest problem is having the time to develop new projects that are challenging and up-to-date. Many teachers find the creation of new projects tricky, because they just don't have time to go on CPD courses let alone create stuff themselves.”*

T28, a subject leader reports that they are aware of a number of ways to improve teaching if the teachers had enough time. The participant also specifically mentions that the projects must be sustainable:

*“Limited time and resources to develop new approaches in a meaningful and sustained way. Though some exciting initiatives/competitions/opportunities to collaborate with industry etc. exist, as enrichment activities (or increasingly teacher appraisal evidence) these require significant time investment on the teacher’s part which adds significantly to the already heavy workload.”*

T15, a subject leader with more than 10 years of experience reported how the specialism of D&T teachers into different subject areas creates time pressures:

*“time in the timetable where certain specialist teachers are only on part time contracts”*

#### D&T Subject Knowledge

Three participants commented on the issue of D&T teachers’ subject knowledge.

T15, a subject leader with more than 10 years of experience reported that individual teachers cannot deliver all of the curriculum:

*“SOW need to be developed and delivered by Technology teachers who have a different technology specialism.”*

T17, a subject leader reported that the knowledge and qualifications of the teachers makes it difficult to deliver the curriculum:

*“Staff knowledge and qualifications related to the technical knowledge aspects of the curriculum.”*

T28, a subject leader commented that the CPD provided is not sufficient to deliver the curriculum:

*“Lack of quality and sustained training”*

#### School and Curriculum Knowledge

Three participants commented on the issues of school and curriculum knowledge.

T15, a subject leader with more than 10 years of experience reported that continuous changes made by the government, presumably the Department for Education, make it difficult for teachers:

*"I am frustrated by the constant government changes"*

T17, a subject leader reported on the how the differences between teachers knowledge and beliefs of what to teach in in D&T cause problems:

*"Too many versions of what makes good D&T teaching - new staff have their own ideas which do not match the school vision. Better clarity about the subject will help this"*

There may also be positive change in allowing new teachers to try out new ways of teaching.

T28, a subject leader commented on the impact of the National Curriculum:

*"The rigidity and demands of the national curriculum (and the resulting expectation to stick to schemes and tick the boxes to raise levels)."*

### Pupils

Three participants' commented on the issues in trying to teach pupils. These comments reflect teachers' opinion on the academic capability of pupils who select D&T. They also reflect the prior teaching of D&T as pupils appear not to have gained sufficient knowledge or skills in the subject.

T17, a subject leader:

*"Student choices at KS4 - typically students who are directed to this subject are lower ability students who have the idea that they can be successful by simply making things. This means that it is harder to work at a more complex level of thinking"*

T28, a subject leader:

*"Accommodating the academic calibre of pupils; particularly at GCSE where DT is often used as a sink subject."*

T18, a subject leader with 1 to 5 years of experience:

*"The kids have no real craft experience, and need to be taught how to use a ruler (they didn't know how to measure) and*

*modelling material, which took far longer than I expected. I'll be looking for pure graphics projects for next year, which means the students will not develop the full range of skills I could teach them."*

T18's comments also demonstrate how the division of the curriculum into the specialise areas restricts pupils learning.

### Equipment

One participant commented on the level of equipment in D&T. T18, a subject leader with 1 to 5 years of experience was positive about the amount of technology available and the budget of the department:

*"We have a full time technician, a laser cutter and 3D printer, but only 5 computers. I have a healthy budget for materials and machines/tools, but very limited space."*

This suggests that even with equipment and budget to develop projects teachers are unable to deliver projects.

## **6.6. Figures for Twilight Sessions and Showcase Lessons**

This section contains the results and evidence collected by other members of the "STEM into Action with D&T" project. It briefly summarises the statistics of attendance on the twilight sessions and the analysis of the teaching showcased lessons that the participants submitted to the project website.

The figures of attendance on the website for the 21 schools in Set 1 are presented in Table 6.18.

Table 6.18 Evidence provided by Set 1

Activity	Number of schools
Attendance at twilights	17
Evidence on website	10
Twilight attendance and evidence on website	8
Returned questionnaire pack	10
Returned questionnaire pack, attendance at twilight and evidence on website	4

Note: Total sample of 21 schools

The figures of attendance on the website for the 61 schools in Set 2 are presented in Table 6.19.

Table 6.19 Evidence provided by Set 2

Activity	Number of schools
Not ordered resources	11
Attendance at twilights	37
Evidence on website	10
Twilight attendance and evidence on website	9
Returned questionnaire pack	21
Returned questionnaire pack, attendance at twilight and evidence on website	5

Note: Total sample of 61 schools

Table 6.18 and Table 6.19 show that 54 of 61 schools attended at least 1 twilight session. The target set for the project was for each school to attend 2 twilight sessions. This target was achieved by 24 of 82 schools.

Evidence of 56 different projects from 20 schools were provided. The resources showcased and the number of resources ordered by all schools are presented in Table 6.20. The table has been sorted in the order of the most ordered resources and only shows resources that were showcased. Of the total 57 different resources available to the participants only one project was not ordered, LED Effects Projector (STEMP051). Of the top ten most ordered resources showcased, five were based on Practical Tasks (STEMP) and five on World of Materials Tutorial (STEMT).

The LED lamp practical task (STEMP017) was the most ordered and showcased by pilot and main schools. This project was frequently discussed during twilight sessions to illustrate the initiative's aims. Participants appear to follow this example, and where resources were seen and used at twilight sessions there is a speculative correlation with ordering, but not showcasing.

The project resources contained link sheets to support a STEM curriculum, however none of showcase example showed links to these. From the 56 showcased projects the following links to STEM were found:

- 4 links to Science departments: active involvement of one Physics and one Chemistry teacher.
- Links to Technology were confined to programming and electronics.
- 1 link to Engineering through mechanisms.
- 1 potential link to Mathematics; after the Enigma Machine practical task delivery it was realised that the mathematics input needed to be

increased, which has subsequently been agreed by the school's Mathematics department.

Table 6.20 Showcased resources of the project

	Number of schools to showcase resources			Number of schools to order resources		
	Exemplar and Pilot	Main	Total	Exemplar and Pilot	Main	Total
Resource Packs available to schools (STEMP = Practical Task, STEMT = World of Materials Tutorial)						
LED Lamp (STEMP017)	4	4	8	16	29	45
Thermochromic Materials (STEMT005)	3	0	3	12	26	38
Memory Metals (STEMT002)	0	1	1	7	25	32
Photochromic Materials (STEMT006)	3	0	3	8	23	31
Smart Phone Kaleidoscope (STEMP008)	4	0	4	8	23	31
Using Your E-Pack (STEMP009)	3	0	3	14	16	30
Glow-In-The-Dark Materials (STEMT007)	1	0	1	9	17	26
Fridge Magnet (STEMP013)	2	2	4	5	20	25
Smartcord Wristband (STEMP020)	2	1	3	5	15	20
Composite Materials (STEMT008)	0	1	1	6	13	19
Spin Art Machine (STEMP026)	2	1	3	7	10	17
Flat LED Torch (STEMP040)	1	0	1	6	11	17
Enigma Machine (STEMP004)	0	1	1	3	13	16
Vibro-Bug (STEMP024)	2	0	2	5	11	16
Metals (STEMT001)	0	2	2	2	12	14
Picture Stand (STEMP015)	0	1	1	0	11	11
Electric Paper Plane Launcher (STEMP045)	1	2	3	3	8	11
Friction Sketch Pad (STEMP007)	1	0	1	3	5	8
Solar Powered Toy (STEMP036)	2	1	3	2	4	6
Powder Pictures (STEMP046)	1	0	1	3	2	5
IQ4 Nightlight (STEMP055)	1	0	1	1	3	4
Garment Safety Light (STEMP043)	1	0	1	1	2	3
Flashing Garment Safety Light (STEMP042)	1	0	1	1	2	2
Crumble	2	2	4			a

Note. a. Data unavailable

Examples of the teaching and learning activities included in the showcase lessons were:

- Using the STEMT sheets as focus practical tasks to enhance pupils' progress in the design and make tasks.
- Homework tasks, extracurricular activities and clubs'.
- Making links to art textiles.
- Whole school activity days and suspended timetables, focussing on STEM.

- Taster sessions, as short projects, to encourage year 9 uptake for GCSE.
- Enterprise activities.
- Links to school tutor system and PSHE to promote teamwork through Year 12 led STEM peer groups (Yrs 7-9).

## 6.7. Discussion and Conclusions

The detailed discussion of findings from this study are presented in Chapter 7 alongside the final discussions of the thesis whereby all the findings can be compared and combined. The key findings for the discussion of work in this chapter were:

- The demographic information about participants in this study. The participants in this study were 61.90% (n = 21, 90% CI [44.32%, 79.48%]) BA creative arts and design degrees. This suggests similarity between the participants of this study and the estimated population data from Chapter 3.
- The levels of teacher engagement with developing technical projects. 11 teachers in this study did not order any resources. Teachers had limited success in developing technology content into the schemes of work created from the resources; only 6 links to STEM were included in the 56 showcased lessons. The most commonly developed resource, ordered by 45 of 82 schools, was a kit to build an LED lamp. This resource was showcased by 8 of 20 schools and there was no evidence of any STEM teaching.
- D&T teachers do not have the time, reported by 10 of 24 participants, or support, to learn everything that is required to deliver the technical projects as their technological starting point is too low. Without a wider understanding of the knowledge required for STEM activities, teachers do not include this content in their lesson and they do not commonly use the STEM knowledge expertise of other teachers.
- Participants reported that they were on average confident in teaching the technical topics of the curriculum. The participants considered that they had made progress in developing their technology teaching confidence during the time of this project.



### **6.7.1. Limitations**

There were high levels of attrition from the original intended sample size of 104, only 82 schools were recruited to the project. This was then followed by high amount of non-response to the questionnaires with only 31 of 82 schools responding. The resulting confidence intervals for the sample power have been calculated at reduced confidence levels (90%, compared to 95%).

Non-random sampling methods were used within the study, and the reduction in the sample size due to attrition may have some effect on the results (Bryman, 2004). This resulted in the combination of results from both samples. The demographic information about the sample was compared to result from Chapter 3 to provide some validation of the acceptability of the sample of teachers. It is difficult to identify all variables in a non-experimental design (Wilson, 2009)

The study suffered from the same self-reporting method limitations as the study in Chapter 5 (Podsakoff et al., 2003; Spector, 2011).

### **6.7.2. Conclusions**

This chapter has presented the results and analysis from a major project providing 82 schools with technology focused CPD and resources for D&T teachers. Teachers' lack of compatible background subject knowledge resulted in the teaching of projects without technical content. This made it difficult for teachers to develop schemes of work to meet the National Curriculum requirements.

The data and findings presented in this chapter can be used to provide validation of the other findings in this thesis. Detailed discussions of all the findings of this study are required with analysis between the findings of Chapters 3, 4 and 5, these are presented within the final discussions in Chapter 7.

## **7. Discussion**

### **7.1. The knowledge and skill requirements for effective teaching of technology**

This research aims to identify the knowledge and skill requirements for teaching technology education in Design and Technology, and to map current provisions in teaching of technology in D&T. Specifically research questions are:

- What is the knowledge background of D&T teachers?
- What influence does teacher knowledge have on technology education?
- What professional development activities can support technology education?
- Are teachers confident in teaching the new National Curriculum?

This final discussion, presents the combined findings from all four studies in this work and considers how triangulation of results between studies can be used to validate findings. The discussion addresses each of the research questions.

### **7.2. What is the knowledge background of D&T teachers?**

Chapter 3 presented the demographic information of D&T teachers. The significant finding of the study was the distribution of background knowledge qualifications for trainee D&T teachers, see section 3.3.4. The study in Chapter 3 calculated that 66.39% (n = 226, 95% CI [57.56%, 75.22%], 90% CI [58.97%, 73.81%]) of D&T teachers gained their background subject knowledge from studying a BA creative arts and design degree. The significance of this result in Chapter 3 was that the majority of D&T teachers had a misalignment in their background knowledge; these D&T teachers did not have the necessary technological subject knowledge to teach the technology in D&T.

Chapter 3 argued that the allowed interpretation of the statutory and non-statutory guidance, by the training institution, for training D&T teachers appeared to, unintentionally, accept craft skills in place of technological

knowledge. Favouring the selection of teachers with design skills and knowledge over technology skills and knowledge. Hence, the large proportion of teachers from an art and design background.

The participants in Chapter 6 were 61.90% (n = 21, 90% CI [44.32%, 79.48%]) BA creative arts and design degrees. A comparison between the sample in Chapter 3 and the sample in Chapter 6 shows an overlap in the values and confidence intervals of the data, see Figure 7.1. A z-test for two sample proportions calculated that there is no significant difference between the two proportions ( $Z = .410$ ,  $p > .05$ , two-tailed). The figure displays the sample confidence interval error bars for each study at 90% confidence level.

The sample of teachers in Chapter 6 have the same background knowledge characteristics as the samples used in Chapter 3 and 4. This is a significant finding as it validates the findings of Chapter 3. The sample in this chapter was more diverse than the one in Chapter 3, which only studied Loughborough University D&T trainees.

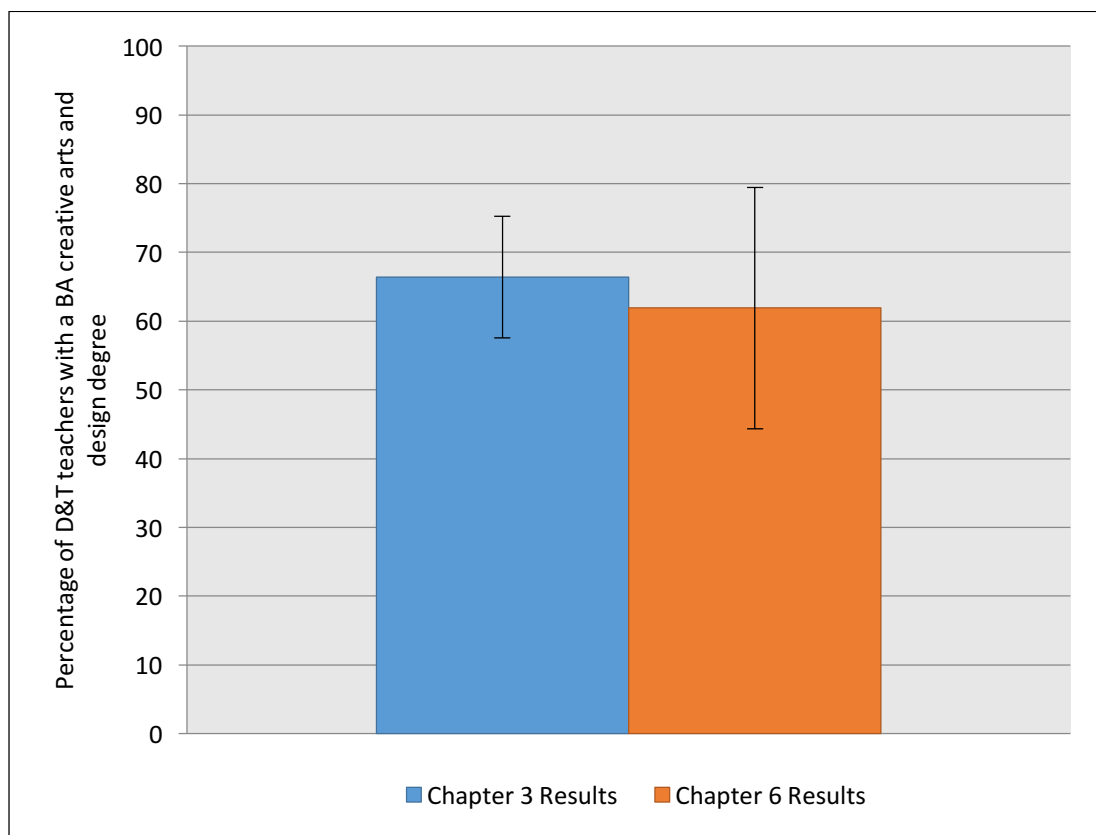


Figure 7.1 Comparison of the majority of participant background experience in Chapter 3 and 6

The standards for training D&T teachers have allowed the creation of a population of D&T teachers where the majority do not have an appropriately aligned subject knowledge background.

### **7.3. What influence does teacher knowledge have on technology education?**

#### Subject and Technological Knowledge Background

Chapter 4 studied the adoption of one project in depth. The results demonstrated that teachers found it difficult to adopt a technology project that included CAD, laser cutting, gear systems and mechanics. Chapter 6 addressed the limitations of studying just one resource for schools and analysed the breadth of the adoption of technological projects by providing 57 different resources to teachers. The resources provided to the participant teachers in Chapter 6 were individually less complex and provided short achievable targets for pupils compared to the Laser Made Mechanical Timer resource studied in Chapter 4. Validation of findings are also provided by the use of methodological triangulation (Guion et al., 2011). These findings have been based on data generated from observational methods in Chapter 4 and the use of closed and open ended questionnaire responses in Chapter 6.

The participants of the studies in Chapter 3 and Chapter 6 had a similar knowledge base. However, the participants in Chapter 6 had more experience. It would have been expected that those with more experience teaching D&T would have been able to accomplish higher levels of technology teaching.

The study in Chapter 6 suffered from very high rates of attrition. Only 9 schools, out of the original target sample of 104, completed all the activities required of them as part of receiving financial support. In set 2, of the 61 schools who signed up to the project only 50 of these schools actually purchased any resources. The schools did not have to complete any questionnaires to receive the £200 credit to spend. This shows that 11 teachers from these schools chose not to select free resources.

The reasons for the withdrawal of schools from the “STEM into Action with D&T” project demonstrate that teachers did not perceive the benefit of

implementing new technology projects. In the four examples the teachers did not realise how the resources could help to improve their curriculum or teaching. Particularly interesting in the situation of the schools undergoing some form of review or inspection. In these two cases teachers were concerned about the potential failure and increased workload of the projects, not considering the potential benefits that delivering new innovative content could provide.

Participant teachers in Chapter 6 demonstrated difficulty in developing new technological schemes of work. Time pressures were the most coded response of negative impact on the study, reported by 10 of 24 participants to the feedback section of the teacher questionnaire.

The Department for Education has prioritised tackling unnecessary teacher workload (Department for Education & Morgan, 2015). The consultation on teacher workload found that teachers considered the level of detail, duplication or bureaucracy for tasks was unnecessary or unproductive not the actual tasks (S. Gibson, Oliver, & Dennison, 2015).

Three influences affecting D&T teachers' ability to develop resources and subsequent technology schemes of work are proposed:

- It has been recognised from the Department for Education consultation on teacher workload (S. Gibson et al., 2015) that teachers are under pressure and that developing new schemes of work does take up teachers' time.
- It is assumed that teachers are motivated to teach their subject and to improve their technological teaching, as they have taken part in the "STEM into Action with D&T" project. Chapter 5 also suggests motivation to improve technological knowledge as 20 participants attended CPD during school holidays.
- It has been identified throughout the studies of this thesis, see sections 3.4.1, 4.4.2, 5.4.3 and 6.7, that D&T teachers have misaligned technology subject knowledge. Therefore, their existing technology and science subject knowledge can be considered incompatible as a result of their background knowledge.

Accounting for these three influences, time is a critical factor and important to teachers. This may be because D&T teachers do not have the time or support to learn everything that is required to deliver the technical projects as their starting point for technological knowledge absent or insufficient in some areas of the curriculum.

Participants' opinions on the success of the "STEM into Action with D&T" project are reflected by the number of positive comments made. Fourteen participants commented that the resources enabled the creation of new schemes of work, 11 participants reported that the project enhanced pupil learning and capability and 7 comments were made about the amount of interest pupil's had in the projects created. This demonstrates that teachers were able to develop schemes of work they considered successful from the resources available. The level of technological content that the participants included in their lessons was low and was confined to basic programming and electronics. The resources were all included with links to STEM learning opportunities, yet only 6 links to STEM were included in the 56 showcase lessons. Only 2 of 27 participants commented that the resources improved pupils STEM learning.

The most popular resource in the "STEM into Action with D&T" project was the LED balancing lamp project, showcased by 8 of 20 schools and ordered by 45 of 82 schools. It would be expected to be popular as it was promoted to the participants during the twilight sessions. The resource had the potential to teach mechanics and utilise mathematics knowledge by requiring pupils to calculate moments to precisely balance the components in the lamp so that it could appear to hang off the edge of a desk. However, as exposed in the showcase data, there was no evidence that any teacher included these activities in the balancing lamp project. Without the calculation and design of the balancing feature the project becomes a very basic exercise of connecting and LED to a battery. The other Practical Task resources have similar low technology level learning outcomes if undertaken without STEM activities or used decoratively rather than scientifically.

This effect of the reduction of technology learning activities in resources was also observed in Chapter 4. In that study participants at 2 of 3 schools

included the teaching of gear theory, but no teachers included teaching of the technical and scientific analysis of the resources.

The questionnaire in Chapter 6 measured teachers' opinion on collaboration with colleagues. The result was teachers' agreement to the statement "It may be argued that in order to provide the best educational experience to pupils D&T teachers should collaborate with colleagues from different disciplines in the application of STEM within D&T projects" (n = 32, Mdn = 6, IQR = 2). This demonstrates that D&T teachers' opinions are that there should be collaboration on STEM content. Thirteen teachers reported having previously collaborated with a colleague in maths and 21 with a colleague in science on a D&T project, out of a total of 32 responses. Yet, the level of STEM collaboration on these resources was low. This suggests that STEM collaboration is rare; and that D&T teachers do not often seek the assistance of science and mathematics teachers to help develop their schemes of work when these topics are required.

In the Chapter 5 study participants did not consider the more scientific aspects of the CPD course relevant to pupils, see Table 5.6. There were also four negative comments made on the session in the CPD course regarding undergraduate engineering. Chapter 5 concluded that the participants could be described as being unconsciously incompetent (Robinson, 1974) with respect to the technical and scientific aspects of the technology in their classroom. The findings of Chapters 5 and 6 suggested that the participants did not have a broader awareness of the STEM subjects.

The quality of the resources is an aspect influencing the adoption of them into classrooms. Concerns were raised by two participants in Chapter 6 about the physical quality of the kits provided, as they were affected by missing parts. Other participants also commented that the resources were not academically sufficient as they did not contain the appropriate theory. This is further evidence to support the hypothesis that teachers do not have sufficient knowledge of the STEM theory that was linked to the resources.

There was better success with the World of Materials tutorials than the Practical Task resources in Chapter 6. This is because teachers did not have to create their own schemes of work to implement these in their classroom as the World of Materials tutorial resources included worksheets that enabled

pupils to investigate material properties and learn without the teacher. The feedback made by one particular participant showed that pupils considered the new materials resources to have the 'wow' factor. These types of materials lessons should not be new to schools as materials have been an important part of the National Curriculum for many years. If pupils are stunned by these projects, then this raises concerns over the existing projects run in that school.

The resources included suggestions of links to the other STEM subjects for participants to make. It was concluded in Chapter 5, that D&T teachers were unaware, unconsciously incompetent, of the technological content they were being expected to learn. Without a wider understanding of the knowledge required for STEM activities, teachers do not include this content in their lessons and they do not commonly use the STEM knowledge expertise of other teachers.

#### Curriculum and School Knowledge

The subject of D&T is relatively novel compared to the other more established areas such as Maths and Science. Consensus on the curriculum knowledge has not been reached, and it is unsure on what exactly should be taught (Banks, 1996a, 1997, 2009b). This has resulted in constant questioning of the D&T curriculum (de Vries, 2006, 2012).

Three participants in Chapter 6 reported that the National Curriculum affected what they wanted to teach in D&T. This was caused by constant changes to the required curriculum and the restrictive bureaucracy.

The complications with specifying exactly what a D&T teacher must know and should teach to pupils was discussed in Chapter 4, see section 4.4.1. It revealed the problems with the interpretation of the standards for teacher training and the D&T Association Minimum Competences for Trainees to Teach Design and Technology in Secondary Schools. Although these documents provide guidance for ITT providers they do not state exactly which technology should be used. Teachers are allowed to decide the specifics of their own knowledge and curriculum (Zanker, 2008). This allows teachers to deliver content they are most comfortable with and does not provide enough detail to encourage teachers to expand their subject



knowledge. This would not be an issue without the problems of misalignment in technology subject knowledge identified above.

Chapter 5 found that technological topics considered important and relevant to pupils by engineering professionals were not considered relevant by teachers. At an individual school there is the collective knowledge of teachers and their practices, referred to as School Knowledge (Barlex & Rutland, 2008; Ellis, 2007b; Shulman & Shulman, 2004). Schools have favoured the teaching of D&T in a carousel system whereby pupils rotate between specialist subject areas, taught by different teachers (Wakefield, 2013). This is used in conjunction with the 'Design and Make' teaching process.

It was discussed in Chapter 4 that using the 'design process' to develop a product should provide the benefit of context and realism to pupils (de Vries, 2007; Dreyfus & Dreyfus, 1980; McCormick, 2004). However, it typically becomes a linear set of tasks for pupils to complete (Mawson, 2003), resulting in the completion of tasks that do not benefit the design or provide learning outcomes (Banks, 2008; Ofsted, 2002).

In Chapter 4, two trainee participants at two schools had to fit the resources into design and make tasks following a strict design process. This was under guidance from experienced teachers at their schools. This introduced unnecessary tasks that do not benefit learning, as it requires pupils to repeatedly follow a process. At the third school in the study, the resource was only delivered in an after school club as the participant/mentor dyad could not fit the resources into the design process. Participants were forced to adopt the school's favoured techniques which diminished the goals of the resources and resulted in familiar teaching practices at the schools. Similar results have been reported in other studies (Banks et al., 2004; Barlex & Rutland, 2008).

School and Curriculum Knowledge can introduce obstacles for teachers trying to develop new technological content. Teachers are prevented from developing schemes of work that do not conform with the schools existing practices. Teachers continue to follow the carousel system and favour the use of the design process for all teaching; which does not follow best practice in D&T teaching (Ofsted, 2012). Flexibility in the National Curriculum allows

too much freedom of choice in regards to the amount of technology that is required to be taught in an individual school. The self-assessment of what to teach allows teachers to ignore the low levels of technological content observed in Chapters 4 and 6.

Reliance on these practices are caused by the personal subject construct of teachers, they believe that these are the right way to deliver the content. This is reinforced by the exam results they receive (Atkinson, 2000b). Results are high, but pupils are being taught to pass the exam and not to gain a deep understanding of technology.

### Pupil Motivation

The demographic of pupil participants in the Chapter 6 study was skewed towards more female pupils compared to males (234 males, 419 females and 306 with no answer given). Comparisons were made between the factor scores between male and female pupils. The descriptive statistics of the start of project pupil questionnaire show that females are in a less motivated and confident starting position compared to male pupils. However, they are less pressured about technology education. Technology is traditionally perceived in schools as a more masculine subject (Colley, Comber, & Hargreaves, 1994) and although the difference in technology subject preference is decreasing it is still favoured by boys (Colley & Comber, 2003; Hasni & Potvin, 2015). The sample in this study appears to show bias towards motivating male pupils in the subject rather than female pupils.

Both the female and male pupils rated themselves as positively motivated towards technology education at the start of the project. This shows that pupils are interested at some level in technology education. The project was however, unable to make improvements to pupil motivation in the subject. There was no significant change in pupil motivation between the start and end of project questionnaires. The skewed sample does not introduce bias towards the changes in pupil factor scores between the start and end of the project. The analysis showed no difference in the change of pupil scores for males and females.

Teachers were able to implement new teaching practices, as demonstrated in the showcase lessons. Pupils reported that learning did take place as there was a significant improvement in pupils' perceived competence scores.

However, these improvements did not result in motivational changes. This project was intended to provide new resources to help teachers achieve an improvement in motivation. Therefore, the inability to improve pupil motivation in the subject is a key finding.

The reasons for no change in pupil motivation were not captured within the Chapter 6 study but they may be explained by the quality of the schemes of work or by teachers' own motivation. Intrinsic motivation requires autonomy (Hill, 2007). Pupils are not more motivated by these projects as they are tasks that do not promote autonomy. There is a connection between teacher motivation and pupil motivation (Atkinson, 2000a). Teacher motivation towards technology may be low as a result of poor understanding of technology, future work should analyse this connection.

There is also an inconsistency between the evidence of motivation provided by pupils and teachers. The statistical analysis of the pupils robustly demonstrates that the project did not improve the motivation of pupils. The detailed breakdown showed motivational improvements in only 6 schools out of 31 schools. However, in the teacher feedback provided, 7 of 27 participants make comments about their perceived motivational improvements in pupils. 3 participants reported that they thought the resources provided relevant context to help teach pupils. Appropriate context should help motivate pupils (Dreyfus & Dreyfus, 1980; McCormick, 2004; Ofsted, 2011a, 2012; Pryde, 2007; Ritz, 2011).

One participant in Chapter 4 did not consider the project to be interesting to pupils, and thought that it might scare them away from the subject. However, the results of Chapter 4 found that pupils did engage with the technical aspects of the resources.

This perhaps demonstrates that teachers do not understand how to sufficiently motivate pupils into the technological aspects of the project. As teachers do not possess a deep understanding of the technological content they are unable to develop appropriate pedagogical content knowledge to teach the technology to pupils (Thanheiser et al., 2010; Williams & Lockley, 2012). Teachers are unable to develop new, motivating, technology schemes of work from provided resources as they do not have the pedagogical content

knowledge in this area. This finding would justify the decline in the number of A-Level D&T students identified in Chapter 1.

### Key Stage 3

Chapter 1 proposed that the subsequent studies should focus on KS3 as this was the last compulsory technology education pupils would receive.

Significant declines in pupils studying non-compulsory technology suggested that this age group was being influenced away from studying technology. The resources studied in Chapters 4 and 6 were for KS3 pupils. The motivational factors discussed above certainly contribute to the problem described.

Specific comments were made by participant teachers in Chapters 4 and 6 on the impact at Year 9 (within KS3). In Chapter 4 one participant commented that Year 9 pupils were uninterested in studying D&T as they had already selected GCSE options that did not include the further study of D&T. In Chapter 6 one participant described Year 9 pupils as having no interest in technology, making it difficult to engage them in learning. These findings suggest that it is critical to motivate pupils and ensure they receive technological learning early in KS3, Year 7 and 8.

### **7.4. Are teachers confident in teaching the new National Curriculum provision for D&T?**

The initial measure of teaching confidence of the participants in Chapter 6 was high, with 16 out of 19 teachers with a positive median score. The initial scores of teaching confidence were also high in Chapter 5, see Table 5.5.

As would be expected, there was a significant positive correlation between the confidence in teaching and the experience of the teacher in the study of Chapter 6.

In Chapter 6 the analysis of individual items of the start of project confidence in teaching questionnaire identified strengths and weakness in particular areas of the curriculum. The strengths were identified as having the range of response positive. The weaknesses were identified as negative median scores. The strengths in teaching confidence were:

- Q1. the classifications of materials by structure
- Q9. using the correct technical vocabulary

- Q16. measuring and marking materials and components accurately
- Q17. the use of CAM for scale of production
- Q19. using hand tools and manual machines
- Q23. health and safety
- Q24. performing risk assessments

The weaknesses in teaching confidence were:

- Q4. designing products with compound gear trains or other similarly advanced mechanical systems
- Q7. building 3D textiles from simple 2D fabric shapes
- Q8. modifying the appearance of textiles using techniques such as dying or applique
- Q13. how to produce products that contain electronic sensors and outputs
- Q14. programming
- Q15. incorporating microcontrollers into their products
- Q22. using CNC milling/turning/routing machines

The items classified as strengths are based on the making of products and using materials. The weaknesses are about the use of more advanced technology such as systems and control of mechanics and electronics, also the use of specific 3D manufacturing technologies that require CAD knowledge. The weaknesses in teaching confidence suggest that teachers are least confident about teaching the areas of technology that required mathematics and scientific knowledge. This is reflected in the low number of STEM links made in the showcase lessons, 6 of 56 showcase lessons. These areas have been avoided in the showcase lesson evidence provided by 20 teachers in this study. Resulting in technology projects with low technological content. One withdrawn school reported they were unable to develop the resources; the data suggests this was because of the required technical content.

The study of the Laser Made Mechanical Timer in Chapter 4 found that trainees were least capable at the teaching of the mechanical systems compared to the operation of the machinery. Participants had knowledge of

how to operate the equipment to get basic results, but did not have a deep understanding of the technology.

Chapter 6 analysed the confidence in teaching scores collected before and after the projects were taught in school. This provided a comparison between the two scores to identify if teachers had used the projects to make improvements to their knowledge and teaching. Overall participants reported that the project and resources had made improvements to their teaching confidence. There was a significant increase in the scores of teacher confidence in technology teaching ( $n = 15$ ,  $Z = -3.150$ ,  $p = .001$ ,  $r = .58$ ). The individual items that had a statistically significant improvement in their scores were:

- Q13. how to produce products that contain electronic sensors and outputs ( $n = 15$ ,  $Z = -2.121$ ,  $p = .031$ ,  $r = .39$ ).
- Q14. programming ( $n = 15$ ,  $Z = -2.232$ ,  $p = .016$ ,  $r = .41$ )
- Q15. incorporating microcontrollers into their products ( $n = 15$ ,  $Z = -2.251$ ,  $p = .016$ ,  $r = .41$ )

This demonstrates that the participants in the “STEM into Action with D&T” study were aware of their weaknesses in teaching electronics. The participants used the resources to develop new electronics schemes of work to address these weaknesses. The opinion of teachers is verified with the feedback comments made by 2 participants that resources have enabled teachers to simplify the learning of electronics for wider groups of pupils.

This finding has the potential to greatly impact pupils’ knowledge of technology. However, evidence from the showcase lessons suggests that these improvements were made using the resources for the LED lamp project, electronic textiles, flat LED Torch, vibro-bug, solar powered toy, electric paper plane launcher and nightlight. As discussed above the actual lessons developed from the resources contain very little technical content as the pupils were essentially just assembling kits without doing any of the potential STEM activities. One teacher’s improved confidence score was with the ‘crumble’ resources that do actually involve the desired programming and control activities.

Fourteen of 27 participants made comments that these resources were new and innovative in their classroom, which suggests that even the low level of technology inclusion from these resources is new to these schools.

Compared to the KS3 D&T technical knowledge learning requirements from the National Curriculum:

- understand and use the properties of materials and the performance of structural elements to achieve functioning solutions,
- understand how more advanced mechanical systems used in their products enable changes in movement and force,
- understand how more advanced electrical and electronic systems can be powered and used in their products [for example, circuits with heat, light, sound and movement as inputs and outputs],
- apply computing and use electronics to embed intelligence in products that respond to inputs [for example, sensors], and control outputs [for example, actuators], using programmable components [for example, microcontrollers] (Department for Education, 2013a).

Five of 27 participants gave positive feedback on the world of materials resources. These comments demonstrate that the resources were new to the school and pupils. The topic of smart materials were specifically named and introduced into the KS3 D&T curriculum over 10 years ago, yet they are novel to the participants of this study (Department for Education and Skills & Qualifications and Curriculum Authority, 2004).

The average percentage of the number of items that have been actually taught by teachers shows that teachers do not teach all of the subject areas of the latest version of the National Curriculum ( $n = 15$ ,  $M = 69.87$  95% CI[62.75, 77.16],  $SD = 13.17$ ) (Department for Education, 2013a).

The findings demonstrate that although teachers consider themselves to be improving in areas they are still falling very short of the requirements of the National Curriculum. There is a lack of awareness in the teachers as to what they should be delivering. The evidence in this study shows that teachers consider the basic electronics they are achieving is sufficient as they consider themselves confident at these tasks.

## 7.5. What professional development activities can support technology education?

The results of the CPD course in Chapter 5 explained that teachers had difficulties making improvements to their scientific and technical content. With no change in response to the first question “I would feel confident teaching pupils about the technical capabilities of a laser” ( $n = 15$ ,  $Z = -.998$ ,  $p = .187$ ,  $r = .18$ ) and a statistically significant improvement in response to “I would feel confident teaching pupils how to use the laser cutter” ( $n = 16$ ,  $Z = -1.903$ ,  $p = .043$ ,  $r = .34$ ).

Participants in the Chapter 6 study were able to take part in as many CPD twilight sessions as they liked. However, participants were requested to attend at least one session. 54 of 82 schools across both samples attended some amount of the CPD activities available. 6 of 27 participants gave positive feedback on the course and reported how it was useful to share ideas with other teachers. 5 of 24 participants responded that they did not receive any beneficial CPD from the project; 2 of these participants did not attend any twilight sessions as they were too far away. Two participants' negative comments reflect that the twilight CPD sessions allow teachers to share project but that they do not develop teachers' subject knowledge. In one of the comments, the participant reports that they do not understand the electronics' subject knowledge and that this prevented them from using the resources.

In response to the question “What are the difficulties you face in delivering the D&T curriculum you want to teach?” teacher subject knowledge was reported by 3 of 5 participants, and the lack of CPD to support teacher was reported by 3 of 5 participants.

Teachers report that peer-to-peer twilight CPD sessions were beneficial to them. However, the use of this CPD method on its own does not provide teachers with the necessary subject knowledge to teach the technical aspects of the curriculum. In these sessions teachers shared project ideas, which were simply repeated in the schools. 8 of 20 schools showcased the balancing LED lamp project without any teaching of mechanics, it is expected that this practice was repeated with the total of 45 out of 82 schools ordering this resource.



The studies in Chapters 4, 5 and 6 all present similar findings; teachers are more confident with the procedural aspects of technology compared to the conceptual knowledge. Participants in Chapter 5 also considered scientific and engineering content to be irrelevant for their pupils. Participants in Chapter 6 make very limited improvements to their technical teaching confidence. These repeated findings suggest that teachers are operating within their 'comfort zone' (M. Brown, 2008; Ecclestone, 2004; Maor, 2004). Ecclestone (2004) found that teaching from the comfort zone covered only the content relevant to the 'Pass' criteria. This teaching is towards the lower levels of the cognitive taxonomy of educational objectives (Bloom et al., 1956).

Participants' inability to develop their own schemes of work with technology content suggests that simply giving teachers classroom resources does not work. Halai (2006) found that the assessment requirements of having to present evidence of teaching for an accredited CPD course had the largest effect on participant improvement. Halai suggests that without this pressure, there would not have been progress. Teachers require appropriate CPD to assist them in their development of technological subject knowledge.

#### Sustainability of teaching resources

For the resources provided in Chapter 6 to be successful in schools and make an impact on pupils they must be sustainable beyond the life of the "STEM into Action with D&T" project. The limited teaching improvements that have been made in Chapter 6 must continue, or progress will revert. The cost burden to schools was reported by 5 of 24 participants; as these resources are made of many different kits. If these schools do not have the funding to continue to purchase these resources then the teaching will stop, making this an ineffective method of delivering CPD. However, it is argued that if teachers had a sufficient grasp of the subject knowledge they would not be reliant on packs of resources to deliver the content as they could create their own resources.

## 7.6. Summary of key findings

The key findings of the discussion are listed:

- The standards for training D&T teachers have allowed the creation of a population of D&T teachers where the majority do not have an appropriately aligned subject knowledge background.
- D&T teachers do not have the time or support to learn everything that is required to deliver the technical projects as their technological starting point is too low.
- Participants inability to develop their own schemes of work with technology content suggests that simply giving teachers classroom resources does not work.
- School and Curriculum Knowledge can introduce obstacles for teachers trying to develop new technological content. Teachers are prevented from developing schemes of work that do not conform with the schools existing practices. Teachers continue to follow the carousel system and favour the use of the design process for all teaching, which reduces the time available for technology teaching.
- The confidence in technology teaching items classified as strengths are based on the making of products and using materials. The weaknesses are about the use of more advanced technology such as systems and control of mechanics and electronics, also the use of specific 3D manufacturing technologies that require CAD knowledge.
- Participants made comments that these resources were new and innovative in their classroom, which suggests that even the low level of technology inclusion from these resources is new to these schools. Compared to the KS3 D&T technical knowledge learning requirements from the National Curriculum
- The findings demonstrate that although teachers consider themselves to be improving in areas they are still falling very short of the requirements of the National Curriculum. There is a lack of awareness in the teachers as to what they should be delivering.
- Both the female and male pupils rated themselves as positively motivated towards technology education at the start of the project. Females having a lower motivation score than males. This shows that

pupils are interested at some level in technology education. The resources introduced by teachers were however, unable to make improvements to pupil motivation in technology.

- Teachers are unable to develop new, motivating, technology schemes of work from provided resources as they do not have the pedagogical content knowledge in this area. This finding would justify the decline in the number of A-Level D&T students identified in Chapter 1.

## **8. Conclusion**

### **8.1. Introduction**

This thesis is concerned with the knowledge and skills required by D&T teachers to deliver technology education. Through four studies, using mixed methods the research aimed to understand what is required of D&T teachers; to determine the characteristics of the population of D&T teachers; and to interrogate if teachers are capable of delivering the technology education required by the National Curriculum. This final conclusion presents a summary of key findings from the studies and outlines the contributions to knowledge of this thesis. The implications of these contributions and recommendations for future work are also presented.

### **8.2. Overview of research studies**

A summary of the key findings from each of the four studies of this thesis follows.

#### **8.2.1. Study 1 – Chapter 3 - Demographic analysis of D&T Teachers**

The literature review identified that limited improvements are made to D&T teachers' subject knowledge during ITT (Atkinson, 2011; Banks, 1997; Benson, 2009) or during service (Micklewright et al., 2014; Ofsted, 2011b). This places a high level of importance on the requirements to teach (Department for Education, 2013b; Design and Technology Association, 2010; SI 2003/1662, 2003) and the subject knowledge that teachers possess before they begin teacher training.

In this study a quantitative approach was utilised to produce a statistical analysis of D&T PGCE trainees at Loughborough University between the academic years 2000-2001 and 2013-2014 inclusive. This study analysed the data of these trainees to identify their subject knowledge background, from their first degree qualification.

The findings from this study revealed the distribution of D&T trainees' prior qualifications, see Figure 3.5. The key finding was that the majority of trainees, 66.39% (n = 226, 95% CI [57.56%, 75.22%]), held a Bachelor of

Arts degree in a creative arts and design subject. The study concluded that a misalignment of D&T teachers' subject knowledge is the cause of teachers' difficulties with technology content in D&T.

The study questioned the suitability of these qualifications in preparing D&T teachers to deliver the technical content requirements of the D&T National Curriculum (Qualifications and Curriculum Authority, 2007). As a creative arts and design qualification would not be able to provide the breadth of technical knowledge required for teaching in D&T. Concerns were also raised as to the suitability of the statutory and non-statutory guidance used to train D&T teachers

By highlighting potential areas of investigation this study established key themes that were investigated and validated in the proceeding chapters.

### **8.2.2. Study 2 – Chapter 4 - Exploring a Technology Project in School**

This study used qualitative methods to observe trainee teachers adopting a novel technology resource created for this study. The Laser Made Mechanical Timer project that was created for the study consisted of a set of resources for pupils and teachers for a curriculum lesson based scheme of work. The project utilised laser manufacturing techniques to enable pupils to design, manufacture, assemble, analyse and investigate their own mechanical timing mechanism.

Models of teacher knowledge domains were used to analyse the actions and opinion of the trainees' participating in the study. The findings of the study were the complexity in specifying exactly which of the available school technologies (Davies & Hardy, 2015) D&T teachers should teach. The National Curriculum and D&T trainee teacher competences are open to interpretation by teachers (Design and Technology Association, 2010; Qualifications and Curriculum Authority, 2007; Zanker, 2008). This meant that although the teaching resources, and teaching expectations, created for the study were compatible with the National Curriculum it could be argued that teachers did not have to specifically know these technologies. However, the purposive sample selected for the study had the relevant laser cutting technology in their schools.

Participants in the study had difficulties in delivering the technological content of the project. The participants were from a creative arts and design

background; the same as identified in the previous study. This demonstrated the effect of the misalignment of teachers' background knowledge to the requirements of technology teaching.

The influence of School Knowledge, the schools historical approach and the combined behaviour of staff and the head of department (Barlex & Rutland, 2008; Ellis, 2007b; Shulman & Shulman, 2004) was also observed to have an impact on developing a new technology based project. The participant/mentor dyads working at the schools in the study focused on developing the resources into the design process. With appropriate subject knowledge the design process should provide the benefit of context and realism to pupils (de Vries, 2007; Dreyfus & Dreyfus, 1980; McCormick, 2004). In this study it resulted in the creation of tasks that do not benefit the design or provide learning, as has been found in other studies (Banks, 2008; Mawson, 2003; Ofsted, 2002).

Teachers are trained into specialist areas which results in an artificial separation of the subject content via a 'carousel' teaching timetable in D&T whereby projects do not contain learning on both materials and mechanics. These specialist areas have been associated with academic regression of KS3 pupils (Gronney, 2013; Ofsted, 2011b).

The significance of the age of pupils was also discovered. Pupils in year 9 were unmotivated in D&T as they had already chosen not to study it beyond their compulsory requirement. This demonstrates the importance of targeting younger pupils to prevent the decline in pupils studying technology subject.

The study concluded that teachers required improvements to their subject knowledge, not just the provision of resources. The training and school environment in D&T creates specialised teachers with gaps in their technical knowledge. Although the study provided useful depth in analysis the sample was small (n =4) and further study would be required to validate claims.

### **8.2.3. Study 3 – Chapter 5 - Testing a technology CPD course**

A mixed methods study was designed to assess the opinions and learning of D&T teachers on a one day technological subject knowledge based CPD course. The CPD course aimed to address the issues with Laser Cutters and levels of technology subject knowledge that were revealed in the previous

study. Participants were sample of PGCE trainees and qualified experienced D&T teachers (n = 20).

The findings of the study were that teachers can operate the machinery they have in the classroom, but do not appear to have a deep understanding of the technology which may limit their ability to teach. Only 6 of 20 participants thought that pupils should be allowed to use the laser cutting machine. This misconception demonstrates how a lack of understanding about the technology limits pupils' opportunity to engage with modern manufacturing technology.

Participants did not make improvements in their confidence in teaching the technical aspects of the course. Participants did not consider the technical and scientific content covered in the course to be relevant to pupils. However, participants made positive gains in their confidence in teaching how to use the machinery and the safety aspects. This demonstrates that D&T teachers are more comfortable with the procedural knowledge of technology than the conceptual knowledge.

Teachers require more support in developing their technological subject knowledge and in how to develop subject knowledge with their pedagogical knowledge. A single one day session was not enough time to develop learning in these topics, considering the low technological knowledge starting point (Trimingham & Horne, 2008).

The participants appeared to only consider the use of technology in isolation and not the integration of technology into other curriculum areas or the purpose beyond the D&T classroom. This was a result of negative reactions to the inclusion of a session on the teaching of engineering at undergraduate level, intended to demonstrate to participants why technology is important in D&T and what it can lead towards.

The study concluded that participants can be described as being unconsciously incompetent (Robinson, 1974) with respect to the technical and scientific aspects of the technology in their classroom. In this instance the teachers do not have enough of a technical background to understand the landscape and purpose of the technology they are trying to teach and this limits their ability to assimilate this content. The study was limited to CPD

provision for only one technical area and the study of other topics are required to validate claims.

#### **8.2.4. Study 4 – Chapter 6 - Studying the implementation of a range of new technology resources by D&T teachers**

Having identified the factors affecting the implementation of a single technology project with a small sample of D&T trainees in Chapter 4, there was the requirement to study the adoption of different projects with a more representative sample of D&T teachers. Validation was also required for the results of Chapter 5; whereby teachers faced difficulties in improving their technological knowledge. A study was required to analyse the range of technological topics that teachers should provide from the National Curriculum.

This study used mixed methods to analyse the teachers and pupils from a sample of 82 schools in London, who were participating with the “STEM into Action with D&T” project. In this project participating teachers could select from a range of 57 resources designed to promote technology teaching with links to STEM. Teachers were given the opportunity to attend peer-to-peer CPD sessions to share project ideas.

The findings of the study were the sample of teachers who responded to the questionnaires had the same background knowledge characteristics as the sample used in the demographic analysis of Chapter 3. The similarity between the teachers used in the two studies provided useful validation to the key findings of Chapter 3, that the majority of D&T teachers have a creative arts and design background, not a technology based one.

Participants in this study had limited success in developing technology content into the schemes of work created from the resources; only 6 links to STEM were included in the 56 showcased lessons. The most commonly developed resource, ordered by 45 of 82 schools, was a kit to build an LED lamp. This resource was showcased by 8 of 20 schools and there was no evidence of any STEM teaching. D&T teachers do not have the time or support to learn everything that is required to deliver the technical projects as their technological starting point is too low. Without a wider understanding of the knowledge required for STEM activities, teachers do not include this



content in their lesson and they do not commonly use the STEM knowledge expertise of other teachers.

Participants reported that they were, on average, confident in teaching the technical topics of the curriculum. Participants teaching strengths were categorised as the making of products and using materials. Their weaknesses were the use of more advanced technology such as systems and control of mechanics and electronics, and the use of specific 3D manufacturing technologies that require CAD knowledge. The weaknesses in teaching confidence suggested that teachers were least confident about teaching the areas of technology that required mathematics and scientific knowledge. The findings of the strengths and weaknesses of teachers technical teaching confidence is in alignment with the findings of Chapters 4 and 5.

The CPD activities focused on the sharing of resources and projects, not on developing teachers' subject knowledge. Although participants reported that they had made significant improvements to their teaching confidence of electronics as a result of this project the evidence of showcase lessons suggests that these gains are overestimated by the participants. The types of activities and projects that participants have developed only contain basic electronics, below KS3 level.

There was inconsistency between the teachers' reports of pupil motivation, and how pupils rated their own motivation towards technology. Teachers considered the resources to be successful at motivating pupils, however, pupils' motivation scores did not change from the beginning to the end of the project.

The study concluded that teachers' lack of compatible background subject knowledge resulted in the teaching of projects without technical content. This made it difficult for teachers to develop schemes of work to meet the National Curriculum requirements.

### **8.3. Contribution to knowledge**

The major contribution to knowledge offered by this thesis is the quantified description and analysis of teachers' subject knowledge. Until now the

literature had only suggested that problems existed with teacher knowledge. (Banks, 1996b; Choulerton, 2015; Evans, 1998; Lewis, 1995; Ofsted, 2008, 2011b) but it was not quantified why D&T teachers have difficulties with technology.

This thesis has presented key findings that suggest there is a misalignment in the subject knowledge of D&T teachers, and the knowledge required to deliver the modern D&T curriculum. Two studies of teachers' background knowledge qualifications found a large proportion of teachers did not have a technology background to support their D&T subject knowledge. Chapter 3 calculated that 66.4% ( $n = 226$ , 95% CI [57.6%, 75.2%], 90% CI [60.0%, 73.9%]) of D&T teachers gained their background subject knowledge from studying a BA creative arts and design degree. This was validated by the findings in Chapter 6 that 61.90% ( $n = 21$ , 90% CI [44.3%, 79.5%]) of the participants had this qualification. There was no statistically significant difference between the two proportions ( $Z = .410$ ,  $p > .05$ , two-tailed). It has been argued in section 3.4.1 that these qualifications would not provide teachers with all the necessary technology knowledge and skills for D&T.

A framework for analysing data was developed from the distinct teacher knowledge domains identified in the literature, Content and Subject Knowledge, Technological Knowledge, Pedagogical Knowledge, Pedagogical Content Knowledge, Curriculum Knowledge, School Knowledge and Personal Subject Construct (Banks et al., 1999; Banks, 1996a; McNamara, 1991; Mishra & Koehler, 2006; Shulman, 1986, 1987; Turner-Bisset, 1999). These separate knowledge domains have been used to identify how the misalignment in subject knowledge has affected teachers ability to deliver the technology curriculum.

Teachers' confidence in teaching the technology topics of the D&T National Curriculum was assessed in Chapter 6. Analysis of the questionnaire in section 6.4.2 and discussion in section 7, established that teachers considered the making of products and using materials to be their strength. Their weakness was the teaching of mechanical and electronic systems, and using 3D manufacturing technology that requires CAD. These quantitative findings were verified by comparison to observations made in section 4.3 whereby participants favoured the teaching of practical skills over the

conceptual technology knowledge. Also in the analysis of section 5.3.2 in which participants reported only making learning improvements in procedural knowledge and the rating of sessions on conceptual knowledge as not relevant to pupils. These results present a new understanding of teachers' technology knowledge and their preference for teaching different aspects of the technology curriculum.

The effect of these strengths and weaknesses in technology teaching were demonstrated in the teaching practices observed in section 4.3, the topics that teachers considered relevant to pupils in section 5.3.2, the reported participant feedback in section 6.5.1 and the evidence of teaching provided in section 6.6. Although reporting being confident in teaching (16 out of 19 teachers with a positive median score), see section 6.4.2, teachers reported having only taught 70% of the technology content within the latest version of the National Curriculum (n = 15, M = 69.9% 95% CI[62.8%, 77.2%], SD = 13.2%). The reported analysis of the showcase lessons produced in Chapter 6 revealed that only 6 of 56 showcase lessons contained links to STEM education. These sections provided the evidence that teachers include low levels of conceptual technology learning in their lessons compared to the expected learning outcomes of the National Curriculum.

A discovery made in the analysis of data was that teachers appear to be unaware of their weaknesses in teaching technology. As identified above, the levels of technology they are teaching are not fulfilling the curriculum requirements, but teachers report themselves to be confident and making progress in their technology teaching. Participants (14 of 27 responses) in section 6.5.1 reported that the resources they were developing were making improvements to their lessons and contained new content. It was however argued in Chapter 7 that the content covered in the resources, such as electronics, smart materials and links to science and mathematics have been part of the National Curriculum for many years and should not be new to the D&T classroom. Teachers did not have a deep understanding of the technology discussed in Chapter 5, see section 5.4.3. The resources created in Chapter 4 were discussed to be suitable for teaching in schools according to the National Curriculum and the Competences teachers have been trained towards (Design and Technology Association, 2010; Qualifications and

Curriculum Authority, 2007), see section 4.4.1. The results showed that participants ( $n = 3$ ) focused on manufacturing and could not demonstrate teaching of the conceptual knowledge of the mechanical design, see section 4.3. It is suggested that the lack of technological background results in a reduced awareness of the wider aspects and purposes for technology. The guidance for the subject guidance does not explicitly state what technology should be taught (Design and Technology Association National Curriculum Expert Group for D&T, 2014), and the choice of projects is given to the teachers (Zanker, 2008). Teachers are unaware of what they are not teaching, and this results in the low level of technology content observed in the studies.

Contributions have also been made to the understanding of pupils who are in receipt of the described technology teaching above, see section 6.3. The study in Chapter 6 measured the level of motivation of pupils. The findings were that in KS3, pupils are motivated in studying technology education, with a higher motivation score for boys compared to girls, see Figure 6.3. Pupils were delivered the types of projects described above, containing little or no technology content. These projects were not able to improve the motivation level of pupils as there was no statistically significant change to the pupil motivation measurements taken at the start and end of the study ( $n = 458$ ,  $Z = -1.427$ ,  $p = .154$ ,  $r = 0.05$ ). There were measured, statistically significant, improvements in pupils perceived competence during the project ( $n = 458$ ,  $Z = -3.994$ ,  $p < .001$ ,  $r = 0.13$ ). Teachers perceptions of the level of pupil motivation in the study were high but inconsistent with the findings from pupils, see section 6.5. Seven of 27 participants reported that the benefits of new resources were an increase in pupil motivation; this was not reported by the remaining 20 teachers. If pupils' motivation towards technology is not being improved by the subject this could be used to explain the reduction in the number of pupils studying technology beyond compulsory education.

The research has demonstrated that the provision of resources is not sufficient to tackle the CPD requirements of teachers. New resources were given to teachers in Chapters 4 and 6 as the solution to improve technological teaching. In both studies the teachers were unable to adopt and deliver the level of technological learning that the resources were

designed for, see sections 4.4.2, 6.6 and Chapter 7. The CPD methods investigated in Chapter 5 supports the conclusion that sustained professional development activities are required for resources to be used effectively. Participants in the Chapter 5 study reported difficulties in transforming their subject knowledge of technology into pedagogical content knowledge, see section 5.3.3, and without this they were unable to improve their confidence in teaching conceptual knowledge.

#### **8.4. Methodological Considerations**

This research used both qualitative and quantitative methods in a mixed methods approach to data generation. Mixed methods have been used to combine data generation methods maximise strengths associated to each method and minimise weaknesses. (Johnson & Onwuegbuzie, 2004; Johnson et al., 2007). Triangulation has been used to combine the analysis of qualitative and quantitative methods to be used for mixed methods research (Cohen et al., 2007; Olsen, 2004). This provides validation of findings through observation of results from more than one perspective (Wilson, 2009). This challenges the criticisms that qualitative data is difficult to validate (Cohen et al., 2007; Johnson & Onwuegbuzie, 2004), as quantitative results have been used to support the qualitative findings.

#### **8.5. Implications for D&T education**

This research has demonstrated the influence that the different knowledge domains of a D&T teacher has on the teaching of technology in school.

There are complex relationships between:

- the subject knowledge of individuals and group of teachers,
- the technical skills of teachers,
- how the D&T curriculum is interpreted and adopted,
- what teaching methods are appropriate and what is currently done in schools,
- what beliefs teachers have about what technology should be taught and what is relevant to pupils.

These factors then determine teachers' ability and willingness to develop technology schemes of work for pupils. The implications for the findings of this research are the use of this new knowledge to:

- explain what is taught to pupils,
- evaluate the training of new D&T teachers,
- develop new methods for supporting the professional development of D&T teachers.

### **8.5.1. Pupils and the Curriculum**

This research has demonstrated the levels of technological content that D&T teachers deliver in their curriculum. The results have shown that many topics, such as electronics and smart materials, which have been features of the D&T National Curriculum for many years are not being taught in schools. Participants in Chapters 4 and 6 revealed that the resources they were being asked to deliver contained content that was new to the school. It has been argued in the discussions that this content can be described as part of the National Curriculum. The methods of teaching that schools used, such as the carousel system, also present obstacles to developing new schemes of work that draw on multiple subject areas.

The new prescriptions for the content of D&T provide greater emphasis on integrating technological learning than previous versions (Department for Education, 2013a, 2015a). The artificial divisions of specialist subject areas have been removed, this has the potential to greatly improve pupil learning opportunities as it enables a more realistic and holistic D&T curriculum. Findings in this research have suggested that the assessment requirements of GCSE D&T were having a negative effect on the freedom of design opportunities given to pupils. The new curriculums also have an increased focus on technological subject knowledge and links to mathematics and science. However, this research has demonstrated that teachers are unable to fulfil the technological teaching objectives of the National Curriculum. The implications of these findings is that pupils are not being taught the technology content that the National Curriculum requires.

### **8.5.2. Training of new D&T teachers**

The existing guidance for the selection of applicants to D&T ITT programmes has not produced teachers that are equipped to deliver the new National

Curriculum. The statutory requirements provided by the Department for Education (Department for Education, 2013b; SI 2003/1662, 2003) and the non-statutory guidance adopted by training providers from the D&T Association (Design and Technology Association, 2010) do not specify with enough detail the types of technology knowledge required. This allows for interpretation of the technology requirements and the admission of a high proportion of trainees with a background in creative arts and design.

This research had discovered the weaknesses in the training standards for D&T teachers and how this affects the teachers' ability to deliver appropriate technology education. The requirement to be a D&T teacher must be updated to reflect the requirements of the new National Curriculum and to be able to deliver the benefits of D&T to pupils. These improvements require more detailed requirements for actual technology knowledge and skills.

The findings of the research also identified the problems within the current body of school and curriculum knowledge. With the switch to school based teacher training, and the termination of university based PGCE programmes there would be no external influences on schools to improve their existing practices. The demographic information in this research shows why school based training will continue to propagate this poor level of technological practice. The comfortable level of technology that is currently taught will continue, as the research has demonstrated that teachers have difficulties in making improvements to technological teaching. It is therefore suggested that the future of D&T ITT does include the input of external teaching and subject knowledge development expertise.

### **8.5.3. D&T professional development opportunities**

This research has identified the problems faced by the current body of teachers trying to develop new technology projects schemes of work based on free resources and project ideas. Their reported weaknesses in teaching were teaching modern mechanical and electrical systems. Teachers do not have the time to learn everything they require to deliver new technology projects. The findings demonstrate that although teachers consider themselves to be improving in areas they are still falling very short of the requirements of the National Curriculum. There is a lack of awareness in the teachers as to what they should be delivering. All of these evidence suggests

that teachers require assistance in improving their knowledge, skills and abilities in technology education.

The findings from the provision of resources to teachers and of the CPD methods included within the studies of this research implies that teachers required external help. They are unable to develop technology resources themselves, with the existing subject knowledge. Although teachers like to share resources with each other, and they perceive benefits from this, the result of Chapter 6 do not suggest that this form of CPD alone is enough. Participants in Chapter 6 showed interest in attending accredited CPD activities.

Teachers require support in developing the subject knowledge in technology. But also in developing new pedagogical content knowledge in order transform knowledge into classroom practice. This was the obstacle to the success of CPD activities provided in Chapter 5 and 6. The detail of suggested CPD activities are proposed in the further work of this research.

## **8.6. Recommendations for future work**

Professional development is an activity that all teachers should participate in (Department for Education, 2013b). The key findings of this research have demonstrated the difficulties D&T have in delivering technology education as a result of their subject knowledge and training. However, it is known that teachers engage in relatively little subject knowledge enhancing CPD (Kimbell, 2012; Micklewright et al., 2014; Ofsted, 2011b). The key findings presented within this thesis, see section 7.6 and 8.3, offer valuable information which can be used to inform the professional development of D&T teachers.

It was a key finding that the provision of classroom resources for technology education, is not enough to support teachers in creating new technology schemes of work, see section 7.5. Although subject knowledge improvements are required, the work in Chapter 5 demonstrates that short courses on subject knowledge do not have sufficient time for teachers to develop pedagogical content knowledge and improve their teaching practice. In Chapter 5 participants demonstrated that they would attend courses in



D&T technology subject areas such as 3D printing, laser processing, health and safety, mechanisms and mechanical systems, electronics, engineering, 3D and parametric CAD. In Chapter 6, 67% (n = 18) of participants reported that they would attend accredited courses with recognised qualifications.

The recommendation is that it is necessary to provide D&T teachers with professional development that:

- Provides a framework that teachers can use to assess their professional development needs in technology. Teachers need to be made aware of the wider subject content.
- Reflects the background knowledge and skills of D&T teachers that have been identified in this research.
- Improves teachers' technology subject knowledge, particularly in the conceptual knowledge of mechanical and electronic systems, and 3D CAD/CAM.
- Improve teachers' confidence in technology teaching, by providing the necessary time and support to allow teachers to combine their subject and pedagogical knowledge.
- Develops knowledge incrementally through a number of stages, to address and develop teacher beliefs in the purpose of technology education. Providing a structure for continued learning.
- Provides motivation and recognition of achievement in professional development through accredited certification.
- Measures the effect of teacher development through continued measurement of pupil performance and opinion.

Through a rigorous programme of professional development, the weaknesses to teachers' technology education capability can be addressed. These CPD activities should be supported by additional research to monitor and evaluate the professional development process. The use of action research techniques by participants on the course may provide greater insight into the progress made by pupils and which methods are most effective.

The suggestion for the most suitable way to achieve these recommendations would be to establish one or more technology teacher training centres across the country. These centres would provide a physical location for teachers to

undertake courses in technology, including having the necessary access to technology teaching laboratories equipped with manufacturing machinery. Courses should be split into tiered technology areas which would allow progression from novice to expert. Each tier would provide courses to develop subject and pedagogic knowledge, and the opportunity to meet experts and other teachers. In order to progress through tiers, teachers would be expected to demonstrate learning by providing evidence from their own improved classroom teaching. Provision of courses from Higher Education would allow courses to be accredited to Masters Level, and would allow the assessment of ongoing D&T teaching performance. This would also provide the opportunity to involve academic research in the development of new training procedures and teaching practice. Ensuring that schools do not become isolated from the latest research findings. The use of university engineering teaching laboratories would also give participants access to industrially relevant technology.

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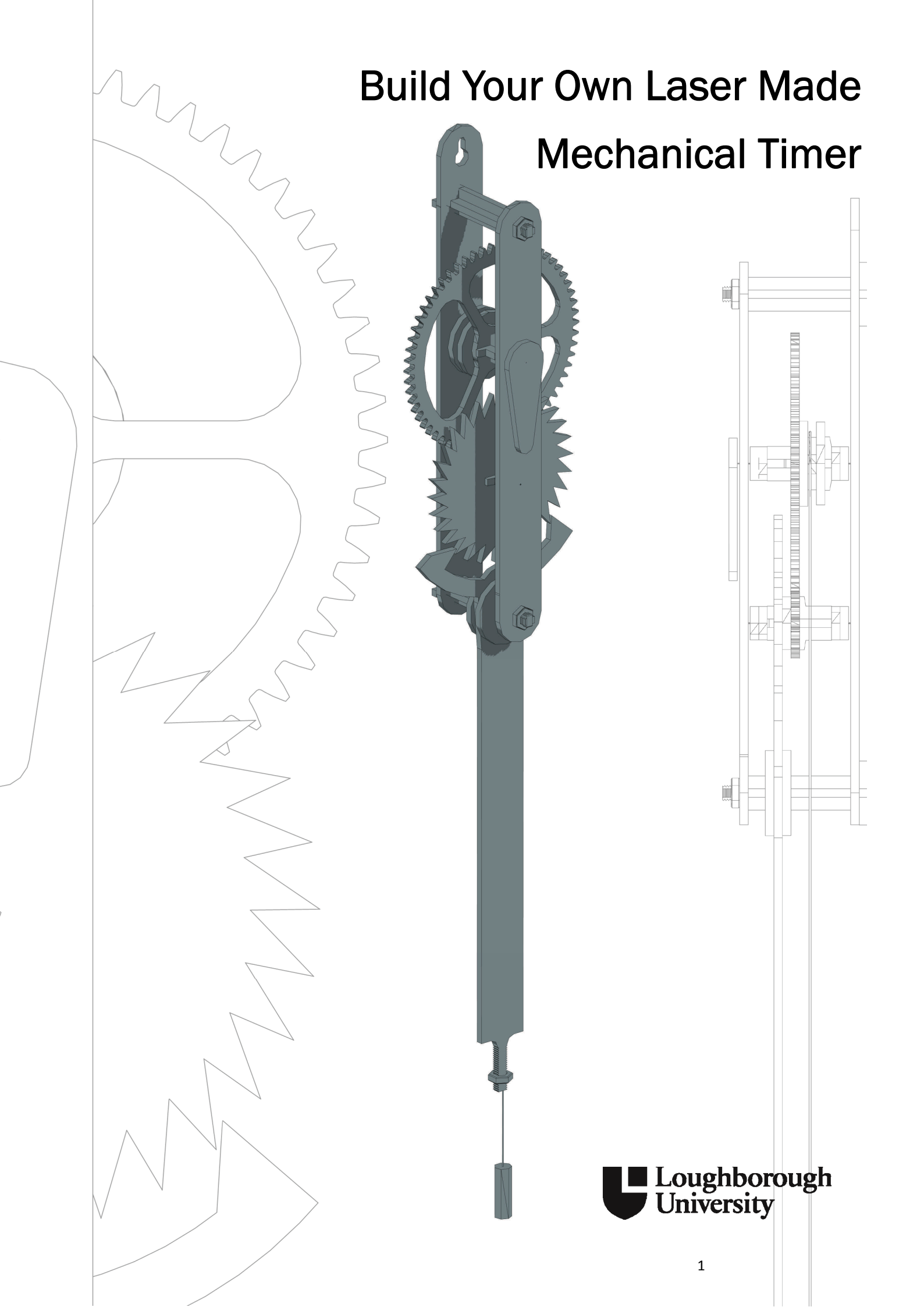
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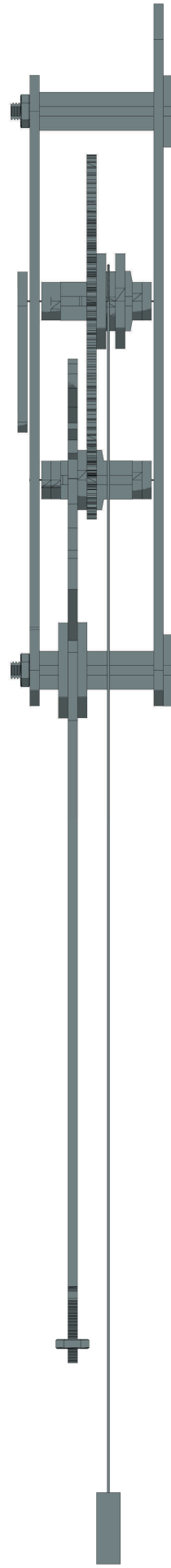
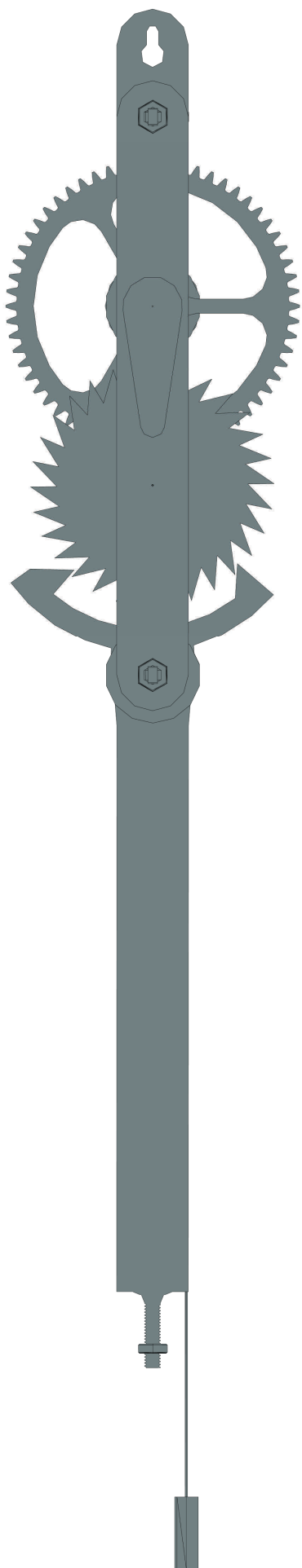
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## **Appendix A - Laser Made Mechanical Timer Assembly Guide**

# Build Your Own Laser Made Mechanical Timer



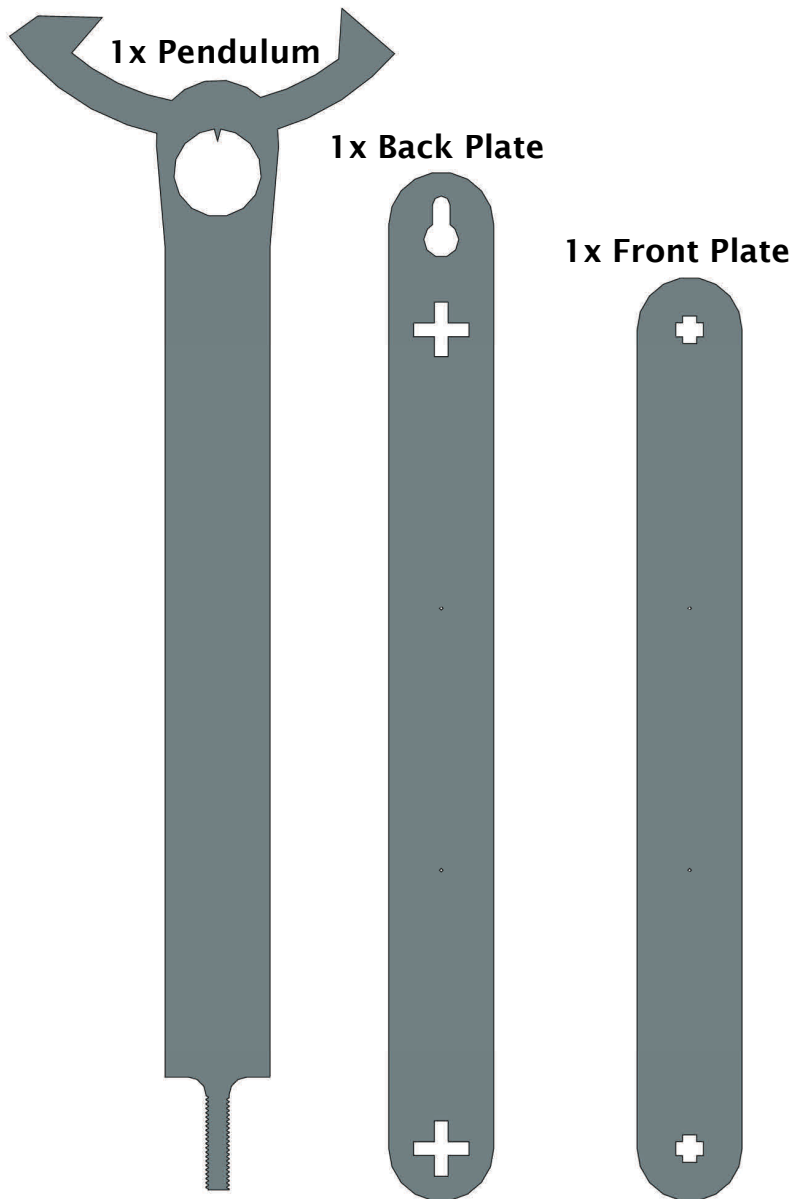




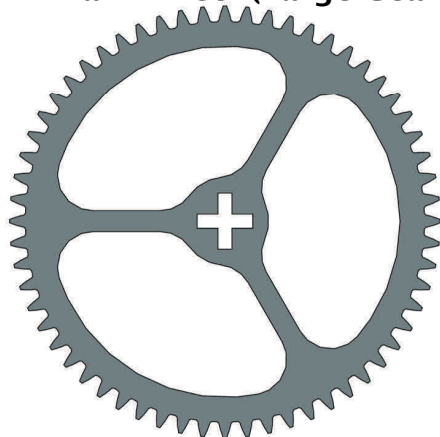
# List of Parts

Before starting assembly, check that you have all the required parts.

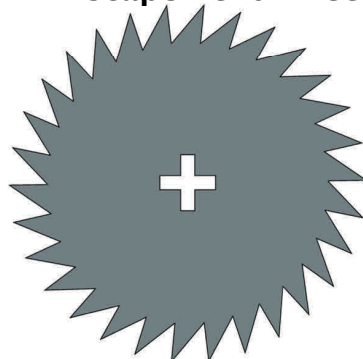
This list also helps you identify all the parts for assembly.



1x Main Wheel (Large Gear)



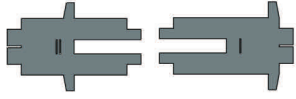
1x Escapement Wheel



# List of Parts

Before starting assembly, check that you have all the required parts.

This list also helps you identify all the parts for assembly.

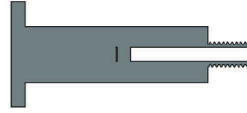
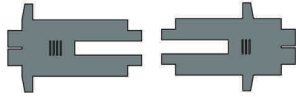


1x Shaft 1

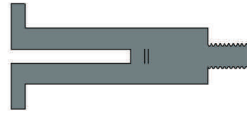
1x Shaft 2

1x Shaft 3

1x Shaft 4



2x Support Arm 1



2x Support Arm 2

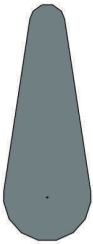
1x Pinion (Small Gear)



3x Nut



1x Hand



1x Pendulum Support



1x Winding Barrel



8x Short Pin



3x Long Pin

1x Hand Pin

1x Small Spacer



4x Large Spacer



4x Bearing Half with Central Pin Hole



4x Bearing Half with Cross



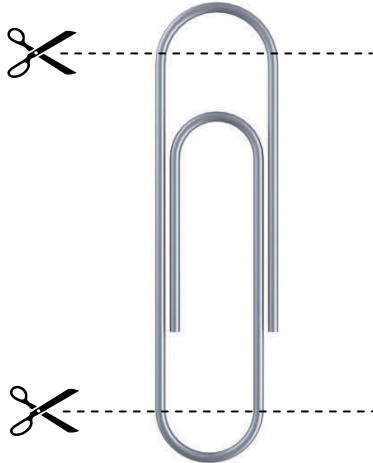
1x Piece of String

1x Weight for String

## List of Parts

Before starting assembly, check that you have all the required parts.

This list also helps you identify all the parts for assembly.

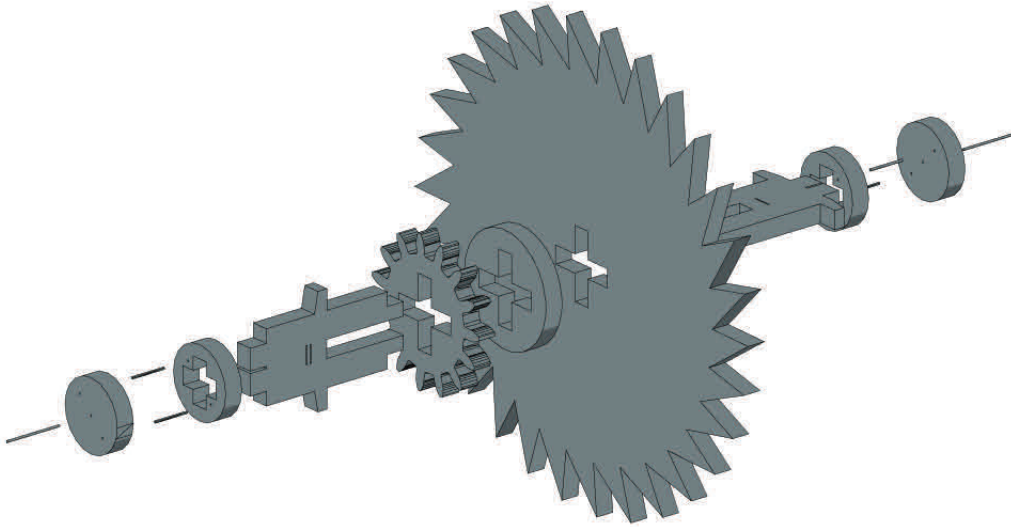


Use a pair of wire cutters to make pins out of paper clips.

You Will be able to make two pins from each paper clip

# Assembly of Escapement Shaft

This is the lower shaft that holds the escapement wheel and the small gear.

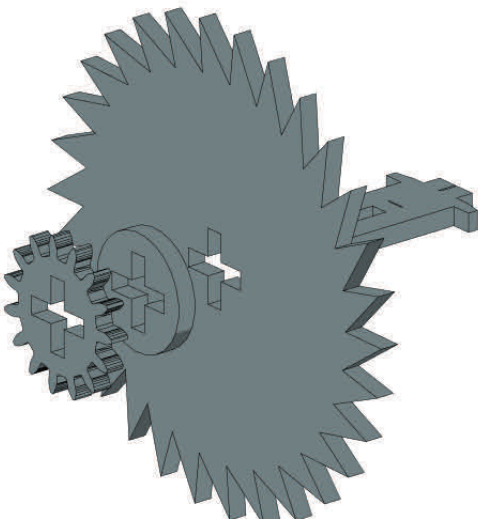


## You will need

- 1x Escapement Wheel
- 1x Small Spacer
- 1x Small Gear
- 1x Shaft 1
- 1x Shaft 2
- 4x Short Pins
- 2x Long Pins
- 2x Pin Hole Bearings
- 2x Cross Bearings

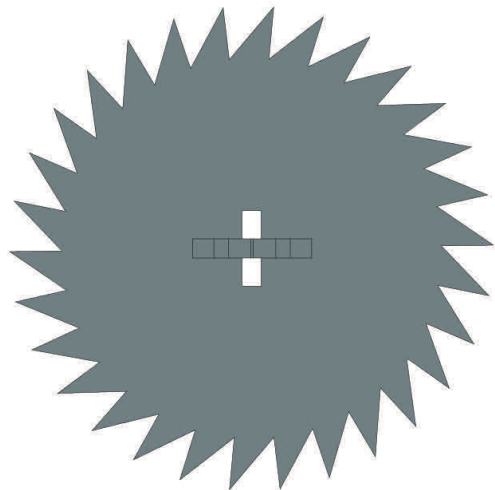
1

Push the escapement wheel, small spacer and small gear onto shaft 1



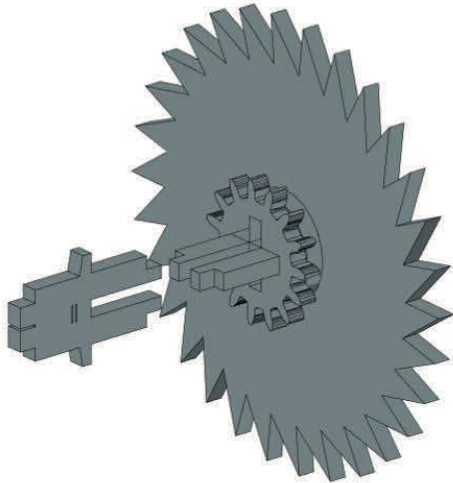
2

It is Important that the escapement wheel is the correct way round. It must look like this from the front.



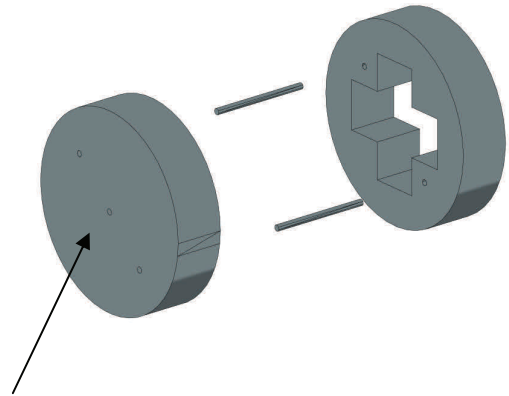
3

Push Shaft 2 through the gap to lock the shaft assembly together.



4

You must now use two short pins to fix together the two halves of the bearing. .

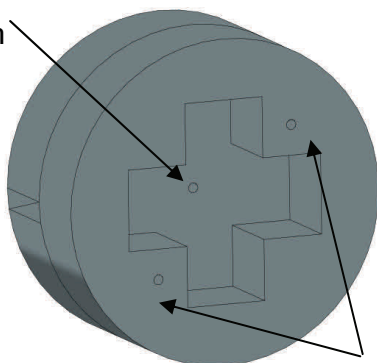


Keep this side of the bearing flat.

5

You need to make two of the bearings in Step 4 . One for each end of the shaft.

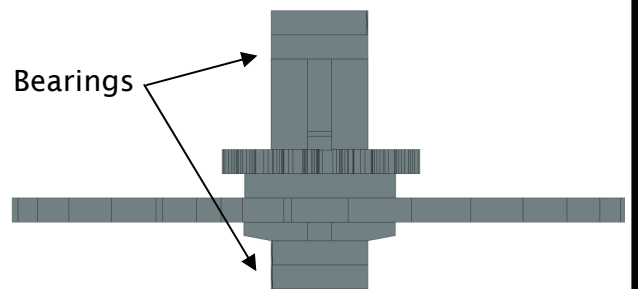
Hole for Long Pin



Short Pins can stick out this side

6

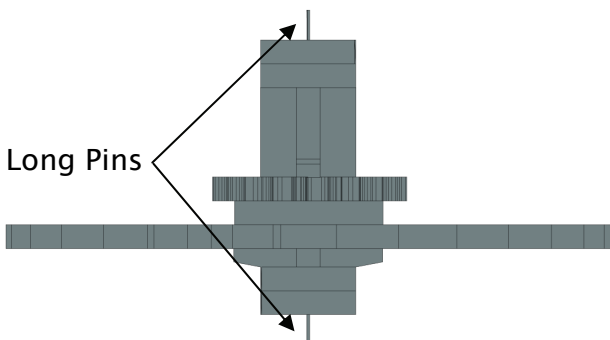
Press the bearings onto each end of the shaft, using the cross shape to hold them in place.



7

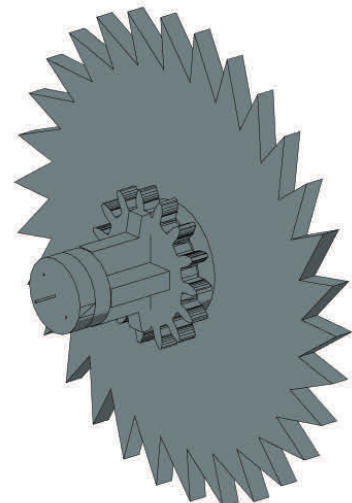
You will need to use the hammer again to push the two longer pins through the bearings and into the shafts. Be Careful not to bend the pins while you do this.

Long Pins



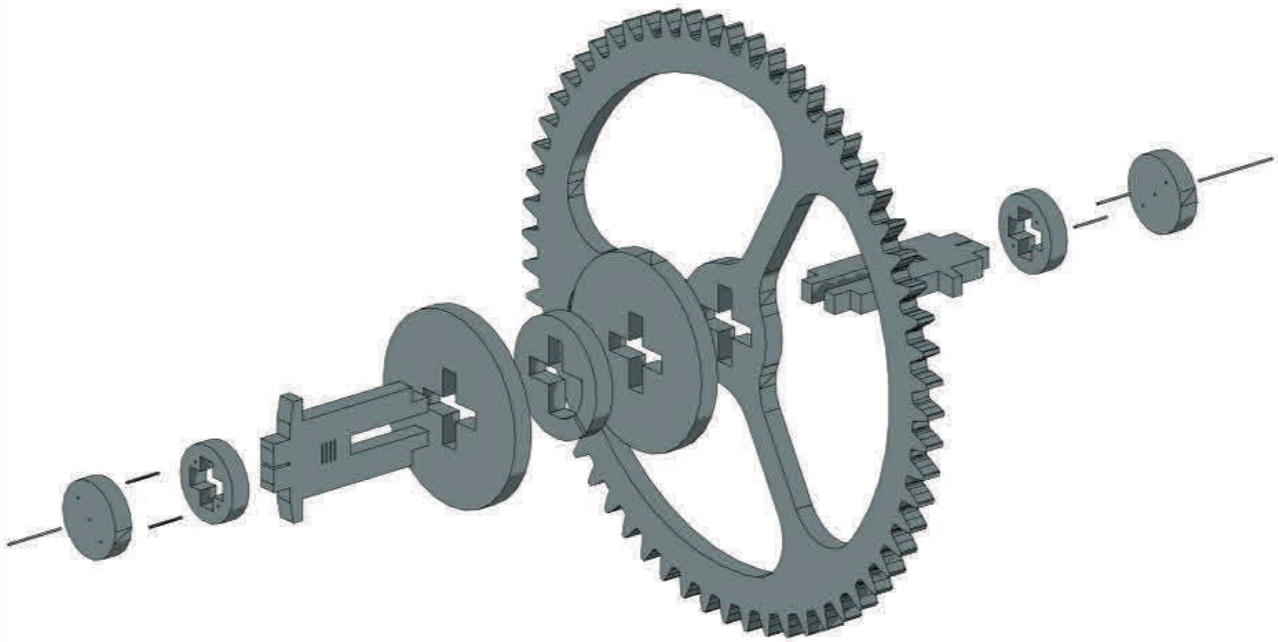
8

This shaft is complete and is ready to be put into the rest of the timer.



# Assembly of Main Wheel Shaft

This is the upper shaft that holds the main wheel and winding barrel.

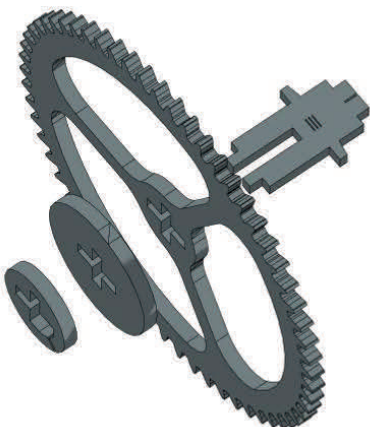


## You will need

- 1x Main Wheel
- 2x Large Spacer
- 1x Winding Barrel
- 1x Shaft 3
- 1x Shaft 4
- 4x Short Pins
- 1x Long Pin
- 1x Hand Pin
- 2x Pin Hole Bearings
- 2x Cross Bearings
- 1x String

1

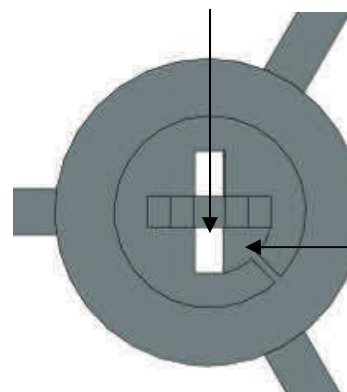
Push the main wheel, 1 large spacer and winding barrel onto shaft 3



2

Tie a knot in one end of your piece of string and insert it into the inside gap in the winding barrel.

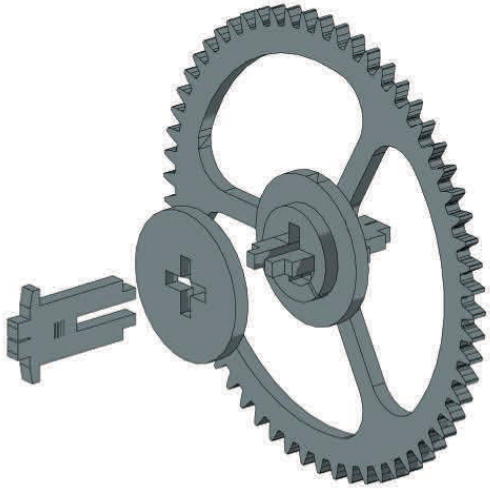
Leave this gap clear for shaft 4



String knot goes here

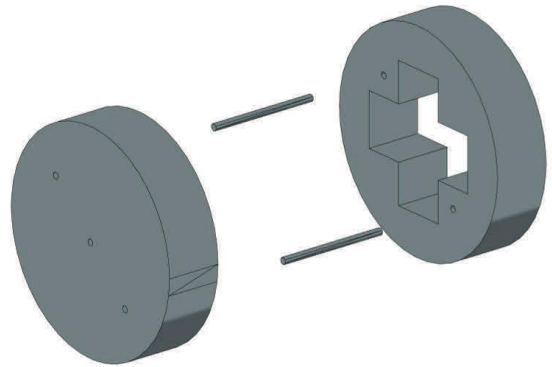
3

Push another large spacer onto shaft 3, and push shaft 4 through the gap



4

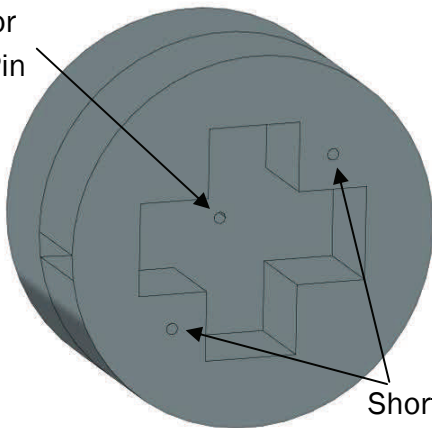
You must now use two short pins to fix together the two halves of the bearing. Use a small hammer but be careful not to hurt your hands or damage the table.



5

You need to make two of the bearings in Step 4. One for each end of the shaft.

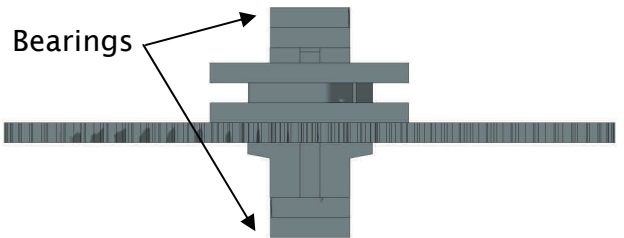
Hole for Long Pin



Short Pins

6

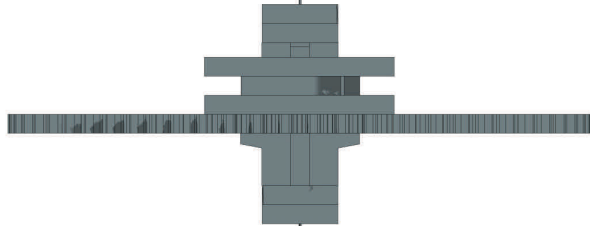
Press the bearings onto each end of the shaft.



7

You will need to use the hammer again to push the two longer pins through the bearings and into the shafts. Be Careful not to bend the pins while you do this.

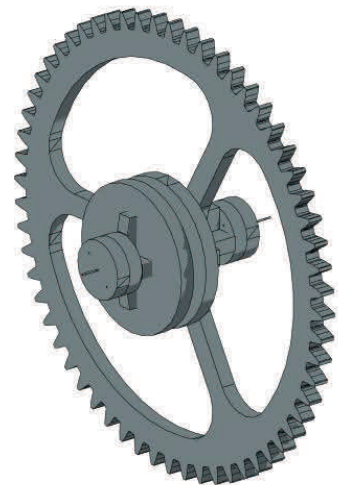
Long Pin



Hand Pin

8

This shaft is complete and is ready to be put into the rest of the timer.





# Assembly of timer Frame

This is the back plate of the timer, the top support arm, and the lower support arm that holds the pendulum.

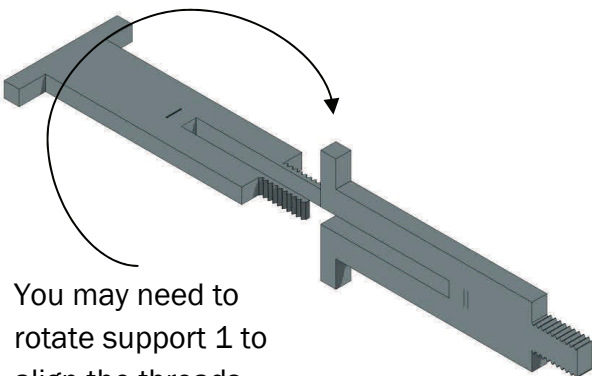


## You will need

- 1x Pendulum
- 1x Back Plate
- 1x Pendulum Support
- 2x Large Spacer
- 2x Support 1
- 2x Support 2

1

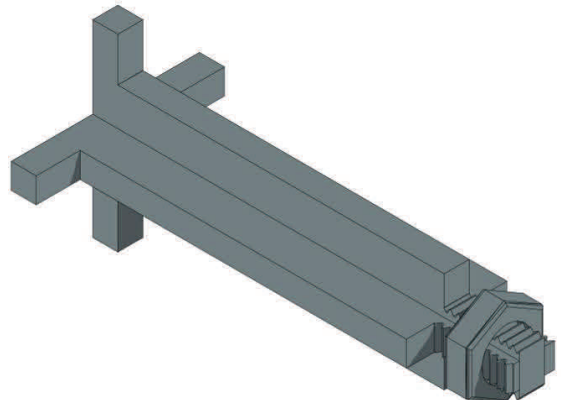
Push Support 1 and Support 2 together. Do this twice to make both support arms.



You may need to rotate support 1 to align the threads

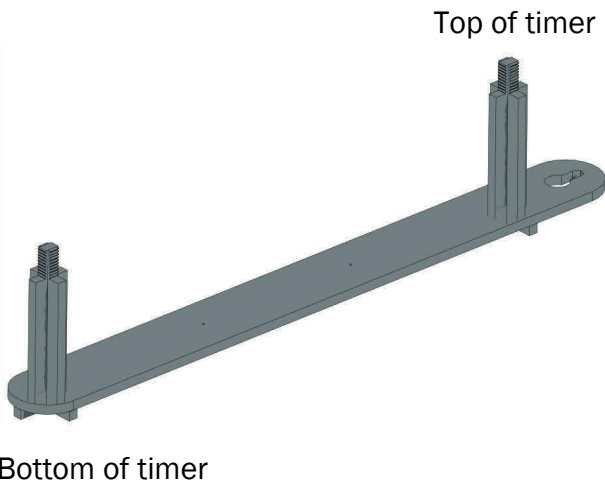
2

Test the threads on the support arm by screwing on a nut. If it does not go on straight then reassemble the arm with support 1 the other way round.



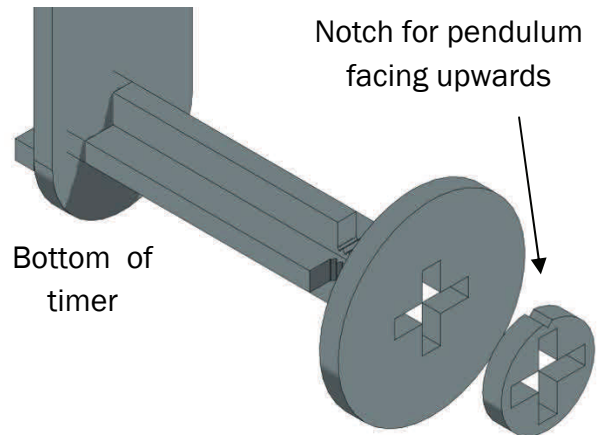
3

Push the two support arms through the back plate



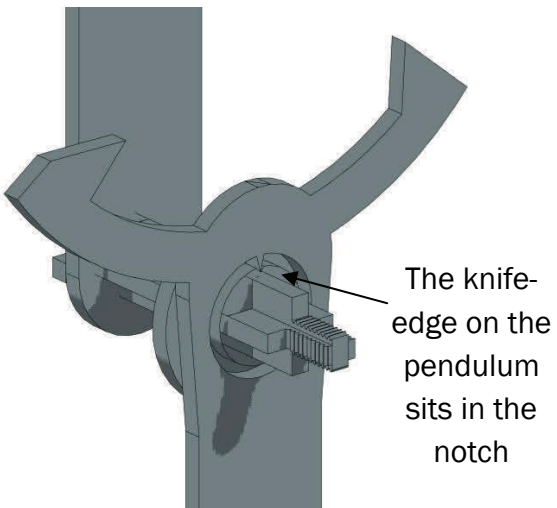
4

Push the large spacer and pendulum support piece onto the bottom support arm.



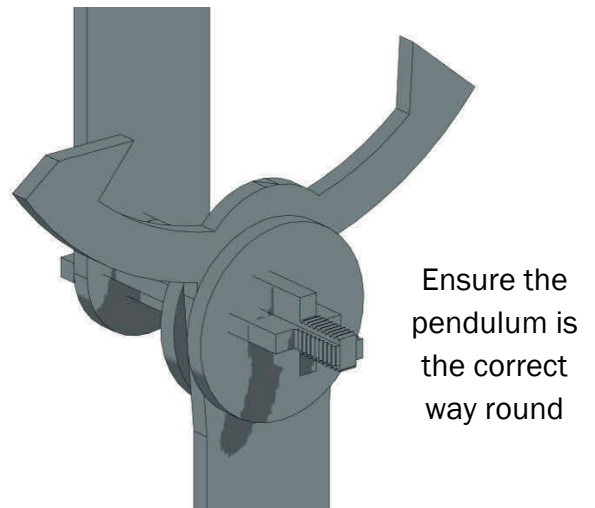
5

Hang the pendulum on the support



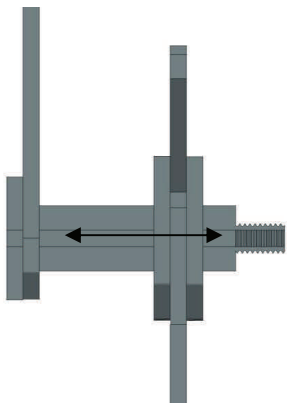
6

Push on the second large spacer.



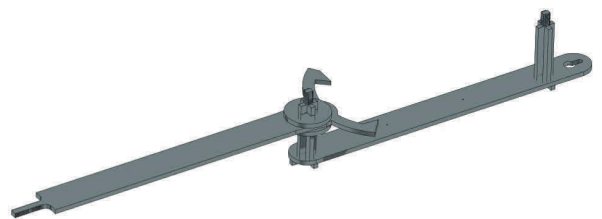
7

The Pendulum and its spacers can be moved back and forth on the bottom support. This allows the pendulum to move out the way while the timer is being moved or wound up.



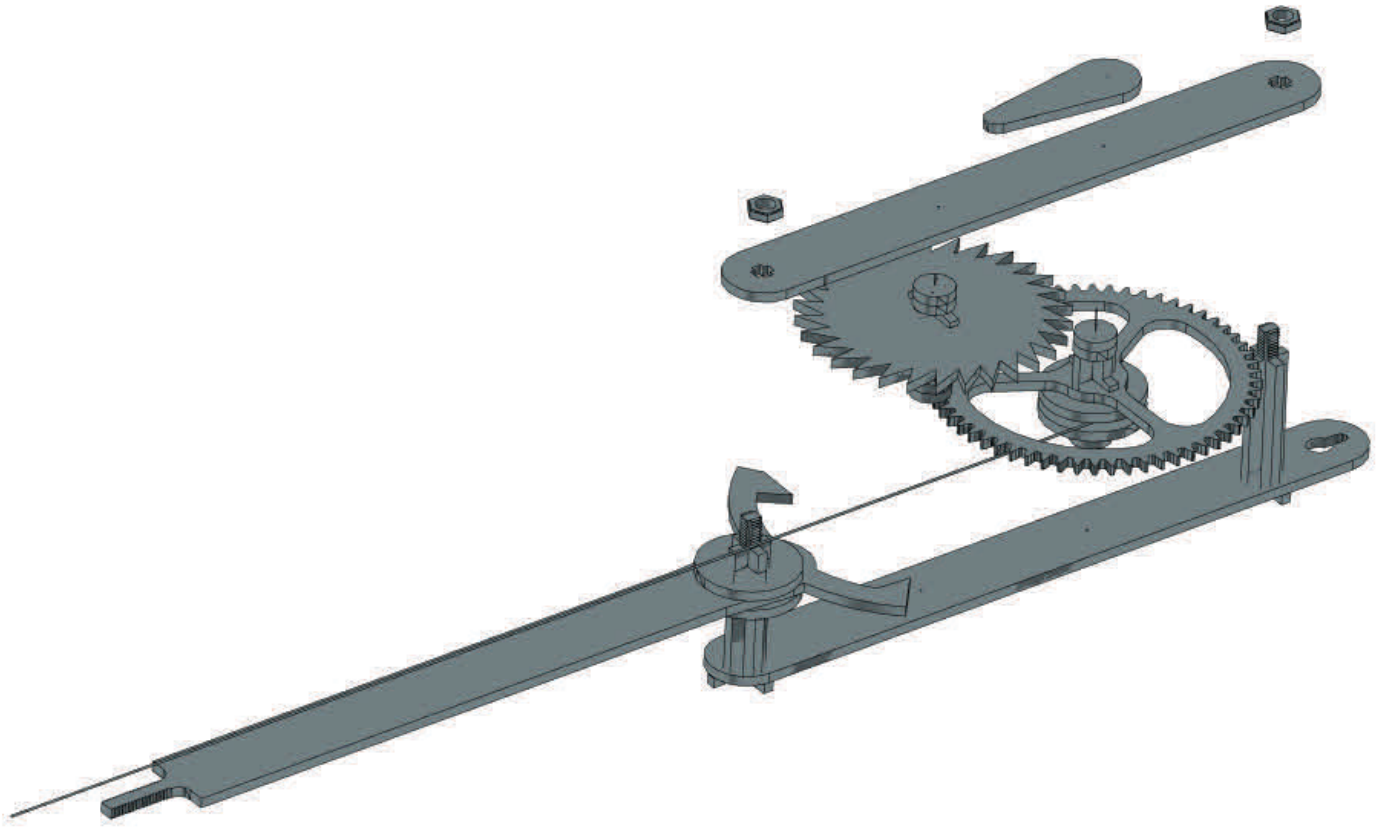
8

The frame and pendulum assembly is complete.



# Final Assembly of timer

Adding the two shafts, front plate and hand to complete the assembly.

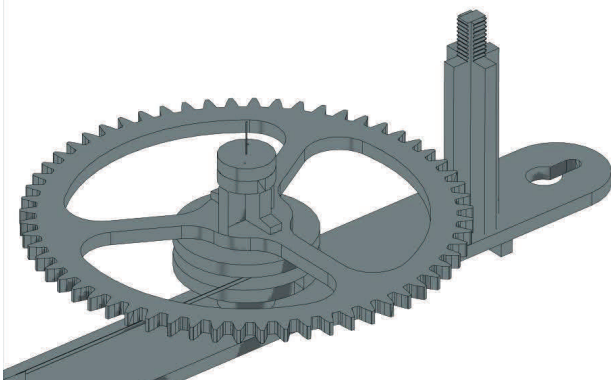


## You will need

- 1x Hand
- 1x Front Plate
- 2x Nut
- 1x Assembled Escapement Shaft
- 1x Assembled Main Wheel

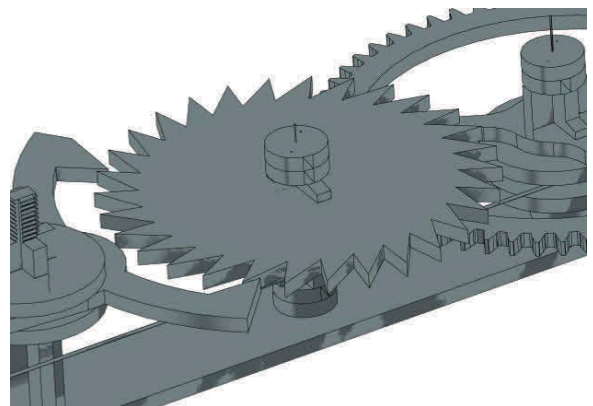
1

Insert the assembled Main Wheel shaft into the top pin hole. Be careful not to bend the pins during assembly



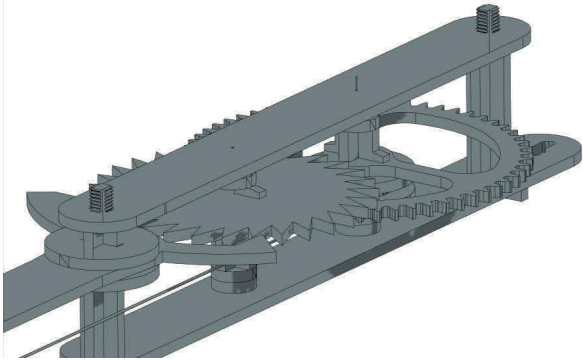
2

Insert the assembled Escapement Wheel shaft into the bottom hole. You may have to rotate the shaft to make the gears fit together.



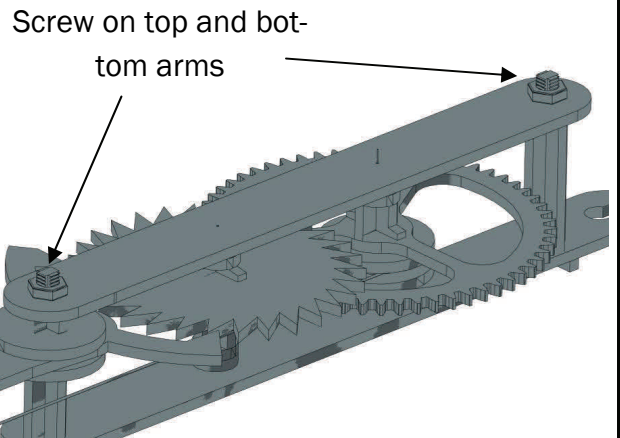
3

Place the top plate on. You will have to be gentle and make sure that both pins go through the holes in the top.



4

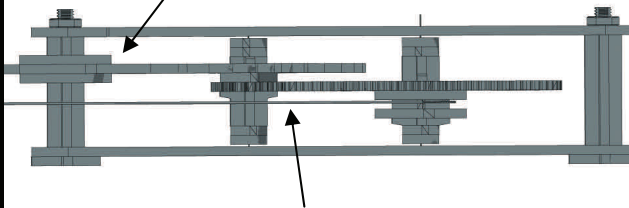
Screw on the two nuts to lock the frame of the timer together.



5

Check that all the gears and pins are in line.

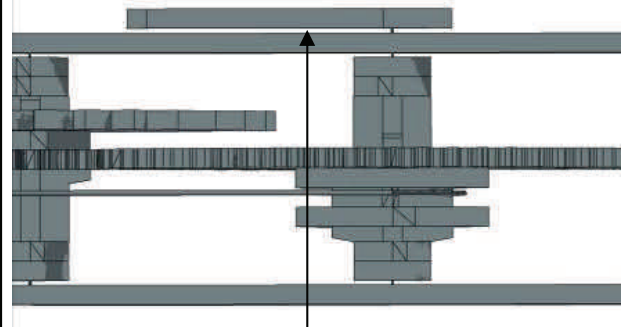
Pendulum can be moved up and down into place



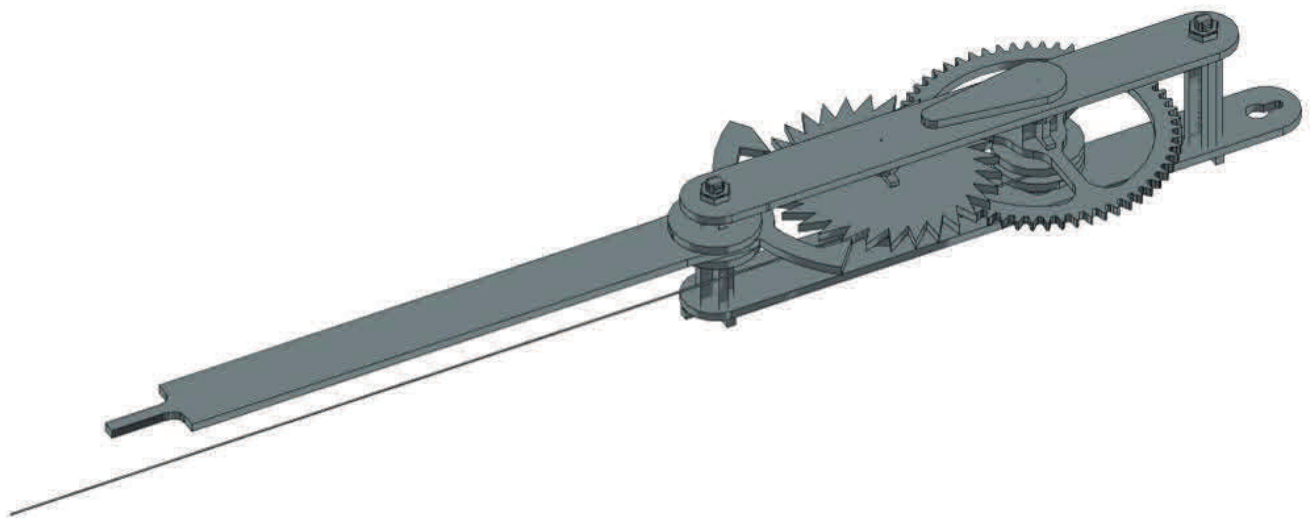
Large and small gear should be engaged and turn together. Both shafts should be straight

6

Gently push the hand onto the hand pin that is sticking out through the frame.



Leave a small gap between the shaft and the front so that it can spin easily.



Assembly of the timer is complete. It is now ready to be hung up and put into motion.

# Testing of the Timer

The first test to see if your timer works.

It will not run at the correct time initially; you will have to make changes to the weight, pendulum and make sure it is set up straight to make it work.

## 1. Hang up the Timer

Make sure that the Timer is vertical and straight or the pendulum will not be able to swing.

## 2. Add weight

Tie your weights onto the end of the string.

## 3. Wind up the gear

Turn the big gear anticlockwise to wind up the string and weight.

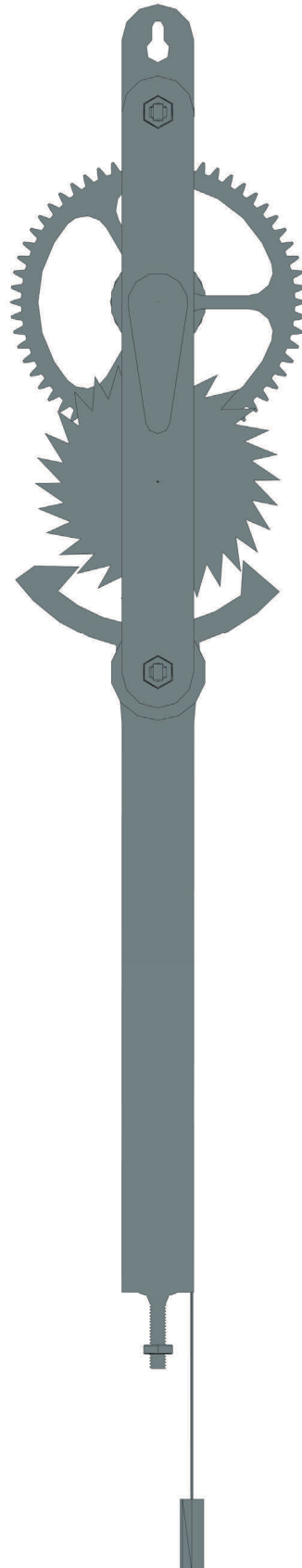
## 4. Swing the Pendulum

Move the pendulum into position by sliding it backwards or forwards.

You must make sure that the pendulum is in-line with the escapement wheel.

## 5. Go

The timer should now be able to run



## **Appendix B - Questionnaires used in Chapter 5**

# Teaching with Lasers - Pre-Course Questionnaire for Teachers

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## Welcome

This questionnaire is for participants of the **Teaching with Lasers** training course. This questionnaire is a requirement for attending the course should be completed before attending the course.

This questionnaire will ask a series of questions related to your current use of laser cutting equipment.

Your responses to this questionnaire will be kept confidential and secure. The information you submit will be used to improve the quality of our resources and training courses. You or your school will not be identifiable in any of the project's results.

The questionnaire should take less than 10 minutes to complete. Once you click 'continue' you will be directed to the first section of the survey. When you arrive at the final 'thank you' page, you will know that your responses have been recorded on our database.

Yours sincerely,

Lewis Jones [PhD Research Student, Loughborough University]E-Mail: [L.Jones@lboro.ac.uk](mailto:L.Jones@lboro.ac.uk)

## Personal Information

This is used to identify that you are a valid participant. The information will not be used to identify your results and your personal information will be removed once verified.

1 Full Name

+ More info

2 Name of School

+ More info

### Consent

By completing this questionnaire you are giving consent to participate. You understand that your data will remain secure. Your responses will only be used as part of the research project investigating the use of Laser Cutters in Schools. You have the right to withdraw your information at any time by contacting the Main Investigator of the project Lewis Jones. Email: L.Jones@lboro.ac.uk



# Teaching with Lasers - Pre Course Questionnaire

This page contains all the remaining questions. Please select one answer for each statement. You can also leave additional comments if you wish. Note that once you have clicked on the CONTINUE button your answers are submitted and you can not return to review or amend that page

## Laser Cutter Questions

The first set of questions are related to your experience and use of laser cutting equipment.

### 3 Your laser cutting experience

	Select you answer			Any other comments
	Yes	No	Not Applicable	
I have used a laser cutter before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I have been trained to use a laser cutter (either by the school or on an external training course)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I have been formally trained in laser safety (either by the school or on an external training course)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

### 4 Laser Cutting

	For each statement, select the extent of your agreement or disagreement.						Any other comments
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Not applicable	
A laser cutter is suitable for resistant materials projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
A laser cutter is suitable for textiles projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

A laser cutter is suitable for electronics projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
A laser cutter is suitable for graphic design projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I am confident in using a laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I understand how a laser cutting machine works	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The school has clear training and/or procedures for safely using the laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I encourage my pupils to use the laser cutter to prototype their ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pupils/students should be allowed to use the laser cutter on their own	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils about the technical capabilities of a laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils how to use the CAD software to produce designs for a laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

I would feel confident teaching pupils how to use the laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils laser safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

5 How many different projects is the laser used for in a typical week

1 a week or less  
 2-5  
 6-10  
 more than 10  
 Other

5.a If you selected Other, please specify:

6 Could you please provide details about your current school's laser cutter. Include information such as make, model, laser type, maximum power.

7 What types of projects and activities is the laser cutter currently used for?

### Design and Technology Project Content Questions

The second set of questions are about the type of content in your lessons.

8 Science Technology Engineering and Mathematics (STEM) Content

	For each statement, select the extent of your agreement or disagreement.						Any other comments
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Not applicable	
STEM is an important part of D&T	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would like to include more STEM content in my D&T lessons	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Mathematics is currently used when designing products in D&T	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Science theory is currently used when designing or analysing products in D&T	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I encourage cross-curricular links with D&T	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The school provides support to pupils about STEM careers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
It is important for a teacher to include technological training as part of their professional development.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

I would like to include more technological training as part of their professional development.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
--	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	----------------------

**Previous Experience Questions**

The final questions are about the training or skills you had prior to becoming a teacher.

9 What degree, equivalent or other qualification did you have before becoming a teacher?

10 What industrial or other experience relevant to D&T did you have before becoming a teacher?

Press continue to complete the survey

# Questionnaire Complete

Thank you for completing this questionnaire.

---

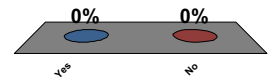
## How to use

- Press the button to select your answer
- You can only select one option in each question
- If you change your mind, just select a new option. Only your last selection will be recorded
- All data collected is anonymous



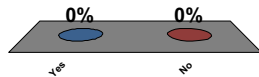
## Have you used a laser cutter before?

1. Yes
2. No



## Have you had any laser safety training before?

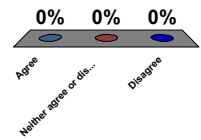
1. Yes
2. No



Response Counter

## Laser safety eyewear should be available for all users?

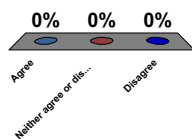
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

## The laser beam is the most significant hazard in a laser cutter?

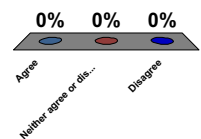
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

## Written procedures should be available for all laser cutters?

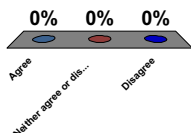
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

It is safe for pupils to use the laser cutter?

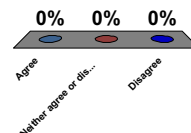
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

Laser safety eyewear should be available for all users?

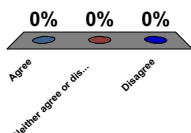
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

The laser beam is the most significant hazard in a laser cutter?

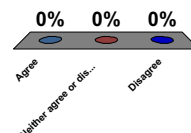
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

Written procedures should be available for all laser cutters?

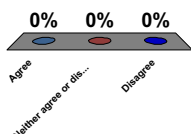
1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

It is safe for pupils to use the laser cutter?

1. Agree
2. Neither agree or disagree
3. Disagree



Response Counter

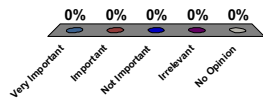
The next questions are about the importance of different aspects of the course.

Are they important to you as a teacher?



## The laser industry

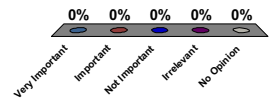
1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

## How a laser works

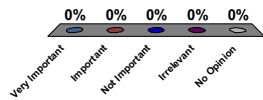
1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

## Details of a laser cutting machine

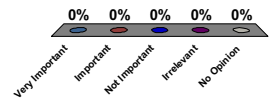
1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

## Details of the laser and materials during the cutting process

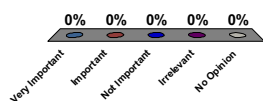
1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

## Laser Safety Legislation

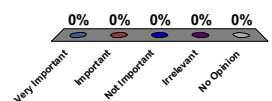
1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

## Practical Laser Safety

1. Very Important
2. Important
3. Not Important
4. Irrelevant
5. No Opinion



Response Counter

# Teaching with Lasers - Course Review

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## Welcome

This questionnaire is for participants of the **Teaching with Lasers** training course. This questionnaire is a review for those who attended the course on 18 February 2014.

This questionnaire will ask a series of questions related to the topics covered in the course.

Your responses to this questionnaire will be kept confidential and secure. The information you submit will be used to improve the quality of our resources and training courses. You or your school will not be identifiable in any of the project's results.

The questionnaire should only take 10 minutes to complete. Once you click 'continue' you will be directed to the first section of the survey. When you arrive at the final 'thank you' page, you will know that your responses have been recorded on our database.

Yours sincerely,

Lewis Jones [PhD Research Student, Loughborough University]E-Mail: [L.Jones@lboro.ac.uk](mailto:L.Jones@lboro.ac.uk)

## Personal Information

This is used to identify that you are a valid participant. The information will not be used to identify your results and your personal information will be removed once verified.

1 Full Name

+ More info

2 Name of School

+ More info

### Consent

By completing this questionnaire you are giving consent to participate. You understand that your data will remain secure. Your responses will only be used as part of the research project investigating the use of Laser Cutters in Schools. You have the right to withdraw your information at any time by contacting the Main Investigator of the project Lewis Jones. Email: L.Jones@lboro.ac.uk

# Teaching with Lasers - Course Review

This page contains all the remaining questions. Please select one answer for each statement. You can also leave additional comments if you wish. Note that once you have clicked on the CONTINUE button your answers are submitted and you can not return to review or amend that page

## Course Content

3 As a Design and Technology teacher rate how relevant each aspect of the course was to you.

	As a Design and Technology teacher rate how relevant each aspect of the course was to you.					Any other comments
	Very relevant	Relevant	Neutral	Irrelevant	Very Irrelevant	
Industrial applications of lasers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
How a laser works	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The different types of lasers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the optical systems and parts of the machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
How a laser beam interacts with materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
What materials can be processed by laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the laser drilling process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the laser cutting process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Laser safety regulations and the different classes of laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

The different hazards in a laser cutter and practical laser safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The use of 3D CAD	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Studying engineering at undergraduate level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

4 In your own future teaching which aspects of the course would be relevant to include in your lessons for students.

	In your own future teaching which aspects of the course would be relevant to include in your lessons for students.					Any other comments
	Very relevant	Relevant	Neutral	Irrelevant	Very Irrelevant	
Industrial applications of lasers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
How a laser works	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The different types of lasers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the optical systems and parts of the machine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
How a laser beam interacts with materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
What materials can be processed by laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the laser drilling process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Details of the laser cutting process	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

Laser safety regulations and the different classes of laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The different hazards in a laser cutter and practical laser safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The use of 3D CAD	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Studying engineering at undergraduate level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

5 The course has improved my knowledge of laser safety

Strongly agree     
 Agree     
 Neither agree nor disagree  
 Disagree     
 Strongly disagree

### Design and Technology Project Content Questions

6 Please state your agreement or disagreement with the following statements about the use of laser cutters in D&T

	For each statement, select the extent of your agreement or disagreement.						Any other comments
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Not applicable	
A laser cutter is suitable for resistant materials projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
A laser cutter is suitable for textiles projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

A laser cutter is suitable for electronics projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
A laser cutter is suitable for graphic design projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I am confident in using a laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I understand how a laser cutting machine works	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
The school has clear training and/or procedures for safely using the laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I encourage my pupils to use the laser cutter to prototype their ideas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pupils/students should be allowed to use the laser cutter on their own	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils about the technical capabilities of a laser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils how to use the CAD software to produce designs for a laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

I would feel confident teaching pupils how to use the laser cutter	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching pupils laser safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

7 Please state your agreement or disagreement with the following statements about the mechanical timer project discussed during the course.

	For each statement, select the extent of your agreement or disagreement.						Any other comments
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Not applicable	
I would feel confident teaching gear theory	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident teaching the mathematics requires to calculate gear ratios	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I would feel confident in teaching the scientific and engineering principals in the mechanism and pendulum	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I do not think there is enough creative opportunity in this project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>



The assembly guide will be useful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Less able students will struggle with this project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

8 Please state your agreement or disagreement with the following statements about the CAD Shoe project discussed during the course.

	For each statement, select the extent of your agreement or disagreement.						Any other comments
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree	Not applicable	
I teach my students to use 2D CAD software (such as Techsoft 2D)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I teach my students to use 3D CAD software (such as ProDesktop, Creo, Solidworks)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
I teach parametric CAD modelling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Students should learn 2D CAD before progressing onto 3D CAD	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

9 Would you take part in other training or CPD courses? Please indicate which topics you would be interested in.

	Please select if you are interested in a particular training course.	
	Interested	Not Interested
3D Printing	<input type="radio"/>	<input type="radio"/>
Health and Safety	<input type="radio"/>	<input type="radio"/>
Mechanisms and Mechanical Systems	<input type="radio"/>	<input type="radio"/>
Electronics	<input type="radio"/>	<input type="radio"/>
Engineering	<input type="radio"/>	<input type="radio"/>
3D CAD	<input type="radio"/>	<input type="radio"/>
Parametric CAD	<input type="radio"/>	<input type="radio"/>

10 Is there any other technology topic that you would like training on?

11 Do you have any other comments or feedback to give on the course.

# Questionnaire Complete

Thank you for completing this questionnaire.

---

## **Appendix C - List of “STEM into Action with D&T” project resources**

Project Name	Description
STEMT001 - Metals	A single lesson or homework activity looking at the properties of metals using small samples of real metals including gold.
STEMT002 - Memory Metals	A single lesson or homework activity that enables pupils to experiment with a length of smart material used in contexts ranging from engineering to garment design.
STEMT003 - Wood Products	A single lesson or homework activity looking at the basic properties of wood using small samples of real materials.
STEMP004 - Enigma Machine	A single lesson or homework activity that introduces the concept of encryption (and an element of history) through a working version of the iconic World War II machine.
STEMT004 - Polymers	A single lesson or homework activity looking at the basic properties of polymers using small samples of actual materials.
STEMT005 - Thermochromic Materials	A single lesson or homework activity that enables pupils to investigate and use small samples of an important category of smart materials used in contexts ranging from medicine to fabric design.
STEMT006 - Photochromic Materials	A single lesson or homework activity that enables pupils to investigate and use small samples of an important category of smart materials used in product design contexts ranging from spectacles to ...
STEMP007 - Friction sketch pad	A short design and make activity that exploits a common smart material to create a novel drawing tool requiring only a stylus to produce marks on paper.
STEMT007 - Glow in the Dark Materials	A single lesson or homework activity that enables pupils to investigate and use small samples of an important category of smart materials used in product design contexts ranging from transport to g...
STEMP008 - Smart Phone Kaleidoscope	A design and make activity that turns a smart phone into a full-screen kaleidoscope as a product in its own right or as an inspirational tool for pattern design.
STEMT008 - Composite Materials	A single lesson or homework activity that enables pupils to handle and investigate a key material underpinning modern advanced composites.
STEMP009 - Using your E-Pack	The E-pack is a unique introduction to key electronic components – focusing on how they can usefully be applied in designing and making. You will see below that we have provided some video to suppo...
STEMT009 - Strange Materials	A single lesson or homework activity that enables pupils to investigate the unusual behaviour of two materials with important product applications.
STEMT010 - Reflective Materials	A single lesson or homework activity which examines the importance and potential of reflective materials and mirrors in product design.
STEMP013 - Injection Moulded Tag	A short design and make activity that enables pupils to experience (and understand) actual injection moulding using simple equipment.
STEMP014 - Photo-Image for a Card Pouch	A design and make activity centred on a photographic process requiring no equipment or special light conditions.
STEMP015 - Picture Stand	A short design and make activity that illustrates the use of easy-bend wire in prototyping to create a minimal product with maximum (retail) value.
STEMP016 - Glow Tag	A short design and make activity that uses an important smart material to create a useful personal product.
STEMT016 - Colour	A single lesson or homework activity that examines the concept of colour and introduces a key analytical technique for colour separation.
STEMP017 - LED Lamp	A design and make activity that uses materials in an economical and ingenious way to create an LED reading lamp of significant size and visual impact. There are three videos available for you to...

Project Name	Description
STEMT018 - Too Small to Measure?	A single lesson or homework that brings to life the concept and importance of precision measurement - using novel and memorable investigations.
STEMP020 - Smartcord Wristband	A short design and make activity that uses an important smart material (encapsulated in polythene) to create a personal product.
STEMT020 - Seeing the Invisible	A single lesson or homework activity that investigates photo-elasticity and enables pupils to visualise and understand important properties of materials.
STEMP021 - Smart Phone Periscope	A design and make activity that turns a smart phone into a full-screen viewing product for use at, for example crowded events.
STEMT021 - Strengths and Weaknesses	A single lesson or homework activity that enables pupils to experiment with a small sample of aluminium to reveal key properties of metals and their implications for engineering and product design ...
STEMP022 - Thermal Image Test Card	A short activity that investigates the principal of battery condition testing (built onto some batteries) as a basis for designing and making a similar product.
STEMP023 - UV Awareness Badge	A single lesson or homework activity that uses a smart material in a simple product design (life saving) context.
STEMP024 - Vibro-Bug	A design and make activity that uses the vibrational effects of an off-centre mass to impart deliberate movement to a toy or 'robot'.
STEMT024 - Electric Motors	A single lesson or homework activity that introduces one of the most ubiquitous components in the made world through practical experimentation.
STEMP025 - Strange Conductors	A single lesson activity that examines the properties of important non-metal conductors in contexts ranging from engineering to fabric design.
STEMT025 - Energy Sources	A single lesson or homework activity that introduces the idea (and importance of) energy harvesting to re-charge batteries in smart phones etc.
STEMP026 - Spin Art Machine	A design and make activity that enables pupils to create a fully functioning spin art machine – and which provides many extension opportunities including the design and making of frames for spin ar...
STEMP027 - Smart-link Automaton	A design and make activity that provides a simple technique for incorporating otherwise impossibly complex mechanisms (e.g., universal joints) into automaton-type products.
STEMT027 - Smart Phone Polariscope	A design and make activity that turns a mobile phone into an instrument for visualising stresses in materials or creating images on screen as a basis for pattern design.
STEMT028 - Theft Alarm	A design and make activity, centering on a SINGLE electronic component, that enables pupils to create an electronic alarm for practically any context.
STEMP028 - Gyro-Spinner	A design and make activity that examines spinning masses (a future energy storage system) through the creation of an electrically powered 'top'.
EDGP029A - Micro-robot positioning	A design and make activity that uses a single (simple) actuation principle to create movement for a vast range of robotic devices.
STEMP030 - Micro-Robo-Rover (single motor)	A design and make activity that invites pupils to create moving robotic devices for use in specific contexts.
STEMP031 - Electric Ball Launcher	A design and make task that enables pupils to create a fully functioning electric ball launcher (for table tennis balls) of the kind supplied commercially for tennis, cricket and football practice.
STEMP032 - Kinetic Art Drawing Machine	A design and make activity that enables pupils to create a simple machine capable of creating an infinite variety of geometrical images on paper – an activity that can embrace, geometry, maths, kin...

Project Name	Description
STEMP033 - Wow, Is That a Clock?	A design and make activity that invites pupils to think about unconventional ways of applying the ubiquitous quartz clock mechanism – mirroring commercial trends in innovation.
STEMP034 - Docking Station	A design and make activity that uses a low-cost uncased stereo amplifier unit as the basis of a high-performance docking station for practically any portable media player.
STEMP036 - Solar Powered Executive Toy	A design and make activity using a solar cell to illustrate energy transfer: from sunlight to mechanical movement.
STEMP038 - Aroma Mood Machine	A design and make activity for the investigation and use of control system(s) in the 'soft' context of a device for accelerating the evaporation of volatile oils. You can download the STEM links ...
STEMP039 Flashing LED Cycle Lamp	A design and make activity using an embedded programmable controller to flash an LED for use on a cycle or similar safety context.
STEMP040 - Flat LED Torch	A design and make activity that uses a minimal number of parts (excluding a conventional switch) to create a credit card size LED torch – and which can also embraces computer generated graphics.
STEMP042 - Flashing Garment Safety Light	A design and make activity that enables pupils to build a simple electronic device into a garment for a functional purpose.
STEMP043 - Garment Safety Light	A design and make activity that enables pupils to build a simple electronic device into a garment for a functional purpose.
STEMP045 - Electric Paper Plane Launcher	A design and make activity that enables the creation of a simple machine for launching paper planes at high speed to compare performance – embracing a range of interesting technical challenges to m...
STEMP046 - Powder Pictures	A design and make activity that uses an electrical system for dispensing powder through a template to create images on surfaces of hot drinks etc.
STEMP047 - Mad Gadget: LED Water Timer	A design and make activity that encourages pupils to think 'outside the box' when creating products such as this simple timer.
STEMP048: Telephone - A Toy or Intercom?	A design and make activity – with references to the history of technology – that enables the creation of a fully working telephone link without batteries.
STEMP049 - LED Effects Projector (Moving Wheel)	A design and make activity based on the fact that one or more LEDs can project an image onto the ceiling of a darkened room. This version - like some commercially available prototypes for disco lig...
STEMP050 - LED Vibro Projector	A design and make activity based on the fact that one or more LEDs can project an image onto the ceiling of a darkened room. This version projects the light through a shallow dish of water electric...
STEMP051 - LED Effects Projector (Water Cell)	A design and make activity based on the fact that one or more LEDs can project an image onto the ceiling of a darkened room. This version projects the light through a shallow dish of water actuated...
STEMP052 - IQ4 Alarm with Buzzer Output	A design and make activity using a programmable device to create an alarm in one of a wide range of possible contexts – an example of embedded microprocessor control.
STEMP055 - IQ4 Nightlight	A design and make activity using a programmable device to create a small light in one of a wide range of possible contexts – an example of embedded microprocessor control.

## Appendix D - Pupil Questionnaire Chapter 6



**Start of Project Questionnaire**

**Project 1 Pupil Number: 1**

Please tick the box to show that your teacher has explained why you have been asked to do this questionnaire.

Your responses on the questionnaire are **confidential** (we do not ask for personal details, and will not share this information with anyone else).

Your answers to this questionnaire will not affect any marks you receive for your work.

You may withdraw your answers at any time without any reason.

Please answer ALL questions.

**Please circle the correct answer:**

I am female

I am male

I do not wish to answer this question

**The following statements are about Technology in Design and Technology. For each of the statements please indicate how much you agree with each of the questions by circling one answer.**

**If you make a mistake cross out your answer clearly and circle the correct one.**

Question	Disagree Very Strongly	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	Agree Very Strongly
This is an example of how to answer the question	1	2	<del>3</del>	4	5	6	7
1. I think that technology projects are boring.	1	2	3	4	5	6	7
2. I feel pressured while doing technology projects.	1	2	3	4	5	6	7
3. I think that technology projects are quite enjoyable.	1	2	3	4	5	6	7

Question	Disagree Very Strongly	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	Agree Very Strongly
4. I am pretty skilled at using technology in D&T.	1	2	3	4	5	6	7
5. I think I do pretty well at technology projects, compared to other students.	1	2	3	4	5	6	7
6. Technology projects do not hold my attention at all.	1	2	3	4	5	6	7
7. I am satisfied with my performance using technology in D&T.	1	2	3	4	5	6	7
8. I enjoy doing technology projects very much.	1	2	3	4	5	6	7
9. I feel pretty confident using technology.	1	2	3	4	5	6	7
10. I think I am pretty good at technology based projects.	1	2	3	4	5	6	7
11. Normally I do not do very well with technology projects.	1	2	3	4	5	6	7
12. I normally do not feel nervous at all while doing technology projects.	1	2	3	4	5	6	7
13. I am very relaxed in doing technology projects.	1	2	3	4	5	6	7
14. I would describe technology as very interesting.	1	2	3	4	5	6	7
15. Technology projects are fun to do.	1	2	3	4	5	6	7
16. I feel very tense while doing technology projects.	1	2	3	4	5	6	7
17. I am nervous while doing technology projects.	1	2	3	4	5	6	7
18. While I do technology projects I think about how much I enjoy them.	1	2	3	4	5	6	7

**Thank you**

**End of Project Questionnaire**

**Project 1 Pupil Number: 1**

Please tick the box to show that your teacher has explained why you have been asked to do this questionnaire.

Your responses on the questionnaire are **confidential** (we do not ask for personal details, and will not share this information with anyone else).

Your answers to this questionnaire will not affect any marks you receive for your work.

You may withdraw your answers at any time without any reason.

Please answer ALL questions.

**The following statements are about the Technology project you have just completed in Design and Technology. For each of the statements please indicate how much you agree with each of the questions by circling one answer.**

**If you make a mistake cross out your answer clearly and circle the correct one.**

Question	Disagree Very Strongly	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	Agree Very Strongly
This is an example of how to answer the question	1	2	<del>3</del>	4	5	6	7
1. I thought that this technology project was boring.	1	2	3	4	5	6	7
2. I felt pressured while doing this technology project.	1	2	3	4	5	6	7
3. I thought that this technology project was quite enjoyable.	1	2	3	4	5	6	7
4. I was pretty skilled using technology in this project.	1	2	3	4	5	6	7
5. I think I did pretty well at this technology project, compared to other students.	1	2	3	4	5	6	7

Question	Disagree Very Strongly	Disagree Strongly	Disagree	Neutral	Agree	Agree Strongly	Agree Very Strongly
6. This technology project did not hold my attention at all.	1	2	3	4	5	6	7
7. I was satisfied with my performance using technology in this project.	1	2	3	4	5	6	7
8. I enjoyed doing this technology project very much.	1	2	3	4	5	6	7
9. I felt pretty confident using technology.	1	2	3	4	5	6	7
10. I think I am pretty good at this technology project.	1	2	3	4	5	6	7
11. This was a technology project that I could not do very well.	1	2	3	4	5	6	7
12. I did not feel nervous at all while doing this technology project.	1	2	3	4	5	6	7
13. I was very relaxed in doing this technology project.	1	2	3	4	5	6	7
14. I would describe this technology project as very interesting.	1	2	3	4	5	6	7
15. This technology project was fun to do.	1	2	3	4	5	6	7
16. I felt very tense while doing this technology project.	1	2	3	4	5	6	7
17. I was nervous while doing this technology project.	1	2	3	4	5	6	7
18. While I was doing this technology project I thought about how much I enjoyed it.	1	2	3	4	5	6	7

**Thank you**

## Appendix E - Teacher Questionnaire Chapter 6

# Teacher Questionnaire for STEM into Action with D&T Projects

This aim of this questionnaire is for the Design and Technology Association to understand the situation in which D&T teachers are faced when teaching technology. It is not an assessment of teaching or learning performance. We wish to establish what existing experience teachers have in technology and how the resources for the projects can help teachers and their pupils.

## Instructions

The questionnaire is in two sections:

Section 1 – To be completed before the start of the project

Section 2 – To be completed at the end of the project

Please complete all questions. Each section should take 10 minutes.

## Your rights

- I understand that I am under no obligation to take part in the study.
- I understand that I have the right to withdraw from this study at any stage for any reason. I will not be required to explain my reasons for withdrawing.
- I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

Name

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Signature

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Date

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## Section 1 – To be completed before the start of the project

Please complete section 1 of this questionnaire before you begin teaching the two projects

<b>Name of School</b>			
<b>Gender</b>	Female	Male	I Prefer not to answer

<b>Title of First Degree</b>				
<b>Degree Type</b>	BA	BSc	BEng	Other
If other please specify:				

<b>What was your route for Initial Teacher Training</b>	Undergraduate	1 Year PGCE	2 Year PGCE
	Teach First	School Direct	Other
If other please specify:			

<b>How many years teaching experience do you have?</b>	Less than 1	1 to 5	6 to 10	More than 10
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<b>What is your position of responsibility in D&amp;T?</b>	Teacher	Subject Leader	Head of Faculty	Other
If other please specify:				

<b>How many half-days do you spend on technology CPD in a typical school year?</b>	Half-days
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<b>Are there any other teachers working with you on the STEM into Action with D&amp;T projects?</b>	No	If yes how many others?
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<p><b>How confident are you about teaching:</b></p>	<p><b>For each of the following statements please indicate your level of confidence in teaching that topic by circling one option.</b></p> <p><b>1 = No Confidence</b>  <b>2 = Unconfident</b>  <b>3 = A little unconfident</b>  <b>4 = Neutral</b>  <b>5 = A little confident</b>  <b>6 = Confident</b>  <b>7 = Complete confidence</b></p>							<p><b>Have you taught lessons on this topic before?</b></p> <p><i>(please circle your answer)</i></p>
1. the classifications of materials by structure? (e.g. hard woods, soft woods, ferrous and non-ferrous, thermoplastic and thermosetting plastics) ?	1	2	3	4	5	6	7	Yes / No
2. how the properties of materials can be used for a design advantage (eg. grain, brittleness, flexibility, elasticity, malleability and thermal)?	1	2	3	4	5	6	7	Yes / No
3. how mechanical systems are used in products?	1	2	3	4	5	6	7	Yes / No
4. designing products with compound gear trains or other similarly advanced mechanical systems?	1	2	3	4	5	6	7	Yes / No
5. how freestanding structures can be made stronger, stiffer and more stable?	1	2	3	4	5	6	7	Yes / No
6. understanding the performance of structural elements to achieve functioning solutions?	1	2	3	4	5	6	7	Yes / No
7. building 3D textiles from simple 2D fabric shapes?	1	2	3	4	5	6	7	Yes / No
8. modifying the appearance of textiles using techniques such as dying or applique?	1	2	3	4	5	6	7	Yes / No
9. using the correct technical vocabulary?	1	2	3	4	5	6	7	Yes / No
10. applying science knowledge in D&T projects?	1	2	3	4	5	6	7	Yes / No
11. applying maths knowledge in D&T projects?	1	2	3	4	5	6	7	Yes / No

How confident are you about teaching:	<p><b>For each of the following statements please indicate your level of confidence in teaching that topic by circling one option.</b></p> <p><b>1 = No Confidence</b>  <b>2 = Unconfident</b>  <b>3 = A little unconfident</b>  <b>4 = Neutral</b>  <b>5 = A little confident</b>  <b>6 = Confident</b>  <b>7 = Complete confidence</b></p>							<p><b>Have you taught lessons on this topic before?</b></p> <p><i>(please circle your answer)</i></p>
12. the basic principles of electronics?	1	2	3	4	5	6	7	Yes / No
13. how to produce products that contain electronic sensors and outputs?	1	2	3	4	5	6	7	Yes / No
14. programming?	1	2	3	4	5	6	7	Yes / No
15. incorporating microcontrollers into their products?	1	2	3	4	5	6	7	Yes / No
16. measuring and marking materials and components accurately?	1	2	3	4	5	6	7	Yes / No
17. the use of CAM for scale of production?	1	2	3	4	5	6	7	Yes / No
18. casting materials in moulds?	1	2	3	4	5	6	7	Yes / No
19. using hand tools and manual machines?	1	2	3	4	5	6	7	Yes / No
20. using 3D printers?	1	2	3	4	5	6	7	Yes / No
21. using laser cutters?	1	2	3	4	5	6	7	Yes / No
22. using CNC milling/turning/routing machines?	1	2	3	4	5	6	7	Yes / No
23. health and safety?	1	2	3	4	5	6	7	Yes / No
24. performing risk assessments?	1	2	3	4	5	6	7	Yes / No
25. 3D CAD modelling?	1	2	3	4	5	6	7	Yes / No

“It may be argued that in order to provide the best educational experience to pupils D&T teachers should collaborate with colleagues from different disciplines in the application of STEM within D&T projects.”

To what extent to you agree with this claim? (please circle one answer)						
Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
1	2	3	4	5	6	7

<b>Have you collaborated with colleagues from mathematics in a D&amp;T project before?</b>	Yes	No
<b>Have you collaborated with colleagues from science in a D&amp;T project before?</b>	Yes	No

**Thank You for completing Section 1**



## Section 2 - To be completed at the end of the project

Please do not complete this section until you have completed teaching of the projects

	<p><b>For each of the following statements please indicate your level of confidence in teaching that topic by circling one option.</b></p> <p><b>1 = No Confidence</b>  <b>2 = Unconfident</b>  <b>3 = A little unconfident</b>  <b>4 = Neutral</b>  <b>5 = A little confident</b>  <b>6 = Confident</b>  <b>7 = Complete confidence</b></p>							<p><b>Have you uploaded resources to the website about this topic?</b></p> <p><i>(please circle your answer)</i></p>
How confident are you about teaching:								
1. the classifications of materials by structure? (e.g. hard woods, soft woods, ferrous and non-ferrous, thermoplastic and thermosetting plastics) ?	1	2	3	4	5	6	7	Yes / No
2. how the properties of materials can be used for a design advantage (eg. grain, brittleness, flexibility, elasticity, malleability and thermal)?	1	2	3	4	5	6	7	Yes / No
3. how mechanical systems are used in products?	1	2	3	4	5	6	7	Yes / No
4. designing products with compound gear trains or other similarly advanced mechanical systems?	1	2	3	4	5	6	7	Yes / No
5. how freestanding structures can be made stronger, stiffer and more stable?	1	2	3	4	5	6	7	Yes / No
6. understanding the performance of structural elements to achieve functioning solutions?	1	2	3	4	5	6	7	Yes / No
7. building 3D textiles from simple 2D fabric shapes?	1	2	3	4	5	6	7	Yes / No
8. modifying the appearance of textiles using techniques such as dying or applique?	1	2	3	4	5	6	7	Yes / No
9. using the correct technical vocabulary?	1	2	3	4	5	6	7	Yes / No
10. applying science knowledge in D&T projects?	1	2	3	4	5	6	7	Yes / No

How confident are you about teaching:	<p><b>For each of the following statements please indicate your level of confidence in teaching that topic by circling one option.</b></p> <p><b>1 = No Confidence</b>  <b>2 = Unconfident</b>  <b>3 = A little unconfident</b>  <b>4 = Neutral</b>  <b>5 = A little confident</b>  <b>6 = Confident</b>  <b>7 = Complete confidence</b></p>							<p><b>Have you uploaded resources to the website about this topic?</b></p> <p><i>(please circle your answer)</i></p>
11. applying maths knowledge in D&T projects?	1	2	3	4	5	6	7	Yes / No
12. the basic principles of electronics?	1	2	3	4	5	6	7	Yes / No
13. how to produce products that contain electronic sensors and outputs?	1	2	3	4	5	6	7	Yes / No
14. programming?	1	2	3	4	5	6	7	Yes / No
15. incorporating microcontrollers into their products?	1	2	3	4	5	6	7	Yes / No
16. measuring and marking materials and components accurately?	1	2	3	4	5	6	7	Yes / No
17. the use of CAM for scale of production?	1	2	3	4	5	6	7	Yes / No
18. casting materials in moulds?	1	2	3	4	5	6	7	Yes / No
19. using hand tools and manual machines?	1	2	3	4	5	6	7	Yes / No
20. using 3D printers?	1	2	3	4	5	6	7	Yes / No
21. using laser cutters?	1	2	3	4	5	6	7	Yes / No
22. using CNC milling/turning/routing machines?	1	2	3	4	5	6	7	Yes / No
23. health and safety?	1	2	3	4	5	6	7	Yes / No
24. performing risk assessments?	1	2	3	4	5	6	7	Yes / No
25. 3D CAD modelling?	1	2	3	4	5	6	7	Yes / No

<b>How would you prefer to learn about teaching new technology?</b>	Please tick all that apply	
	Video and Paper guides (to teach yourself)	
	Online guides (to teach yourself)	
	Demonstrations and discussion from other teachers	
	Short (1 Day) courses	
	Accredited courses from a university that will lead to a recognised qualification	

<b>What was the best thing about the project?</b>	
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<b>What was the worst thing about the project?</b>	
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**Thank you for completing the questionnaire. Please return this along with your pupils' questionnaires to the Design and Technology Association.**